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Carbon Monoxide Asphyxia: The Problem of Resuscitation

Industrial Medicine in 1922

The Ventilation of English Factories and Workshops in Hot Weather

The Influence of Benzol upon Certain Aspects of Metabolism

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THE JOURNAL OF INDUSTRIAL HYGIENE

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CARBON MONOXIDE ASPHYXIA: THE PROBLEM OF RESUSCITATION*

CECIL K. DRINKER, M.D., AND WALTER B. CANNON, M.D.

INTRODUCTION

THE problem of resuscitation from carbon monoxide asphyxia possesses far greater complexity than is offered in the case of resuscitation either from drowning or from electric shock. In these latter cases, as Henderson and Haggard (1) have pointed out in the first report of this Commission, the patient is practically saved when respiration has been restored. There is little or no question of effects which may express themselves hours or even days afterwards. Furthermore, these two common types of accident are essentially acute. In drowning, for example, the heart may be experiencing the effects of acute asphyxia at the moment when artificial respiration is started, but it has not been subjected to a prolonged period of gradually developing oxygen lack, as may readily be the case in carbon monoxide poisoning. Another important element in carbon monoxide asphyxia is found in the fact that gassed patients may pass through a prolonged period of unconsciousness both before and after natural respiration has been restored. While in drowning there is, of course, aspiration of water into the air passages, the water which is not emptied out during the measures utilized for resuscitation is usually absorbed rapidly and causes no damage. In carbon monoxide asphyxia, on the other hand, there is considerable evidence of the existence of pulmonary congestion and of overproduction of fluid in the lungs and the bronchial tree, and the presence of this fluid must be kept in mind when one considers the best sort of artificial respiration to employ.

Before making an actual examination of artificial respiration, the authors have felt it wise, first, to obtain knowl-

*Report II of the Commission on Resuscitation from Carbon Monoxide Asphyxia. Personnel of the Commission: Cecil K. Drinker, M.D., Associate Professor of Applied Physiology, Harvard Medical School, Chairman; Walter B. Cannon, M.D., Professor of Physiology, Harvard Medical School; David L. Edsall, M.D., Dean of the Harvard Medical School, and Professor of Clinical Medicine, Harvard Medical School; Howard W. Haggard, M.D., Instructor in Applied Physiology, Yale University; Lawrence J. Henderson, M.D., Professor of Biological Chemistry, Harvard Medical School; Yandell Henderson, Ph.D., Professor of Applied Physiology, Yale University; Francis W. Peabody, M.D., Professor of Medicine, Harvard Medical School; Royd R. Sayers, M.D., Chief Surgeon, United States Bureau of Mines, Washington, D.C.; and Charles B. Scott, Bureau of Safety, American Gas Association. Received for publication Jan. 15, 1923.

edge of the current practice in resuscitation in the gas-producing industry of the country and, secondly, to examine more thoroughly than has been done in the past the clinical course of gassed patients who have received hospital treatment.

Section I. Present Practice in Resuscitation from Poisoning by Illuminating Gas

After communicating with Mr. Oscar H. Fogg, Secretary-Manager of the American Gas Association, we sent to a group of seventeen large gas producers an explanatory letter and the following questionnaire:

Questionnaire

1. What is your present organization for dealing with gassed cases?
2. How have the individuals in charge of this work been trained?
3. Do you issue any general instructions to foremen, etc., relative to artificial respiration?
4. What equipment do you provide for your resuscitation team? Why has this equipment been chosen?
5. If possible, forward records of all cases treated for gas poisoning by agents of your company during the past five years. It is important that these records include notes as to whether the patient was breathing when treatment began; how long the treatment continued; any details available as to the immediate and future condition of patients who recovered.
6. Forward any comments upon the resuscitation problem which have not been covered by the preceding questions and which you believe may be of service to the committee.

The following firms received this request for information:

1. The Consolidated Gas Electric Light and Power Company of Baltimore.
2. The Boston Consolidated Gas Company.
3. The Brooklyn Union Gas Company.
4. The Peoples Gas Light and Coke Company of Chicago.
5. The Denver Gas and Electric Light Company.
6. The Detroit City Gas Company.
7. The Georgia Railway and Power Company.
8. The Southern California Gas Company.
9. The Milwaukee Gas Light Company.
10. The New Haven Gas Light Company.
11. The Providence Gas Company.
12. The Public Service Gas Company of Newark.
13. The Consolidated Gas Company of New York.
14. The United Gas Improvement Company of Philadelphia.
15. Portland Gas and Coke Company.
16. The Rochester Gas and Electric Corporation.
17. The Laclede Gas Light Company of St. Louis.

These widely scattered organizations may be considered to represent the experience of gas producers in this country. All except one replied, and usually in great detail.

In summarizing the answers received, it is possible to treat the questions together. In all cases, one is impressed by the effort that has been made to place resuscitation upon a practical basis. In most instances this work is allotted to carefully trained rescue crews on duty in shifts so that all calls can receive immediate attention. Occasionally larger groups of responsible employees, headed by a superintendent and extending down through sub-foremen, have received first-aid instruction, the size of the group ensuring the availability at all times of someone competent to render assistance.

If, now, we systematize the information received in regard to the methods of resuscitation actually used, we find that in all cases the Schäfer, or prone pressure, method of artificial respiration is taught. Whether or not the chief reliance is placed upon this method is another matter. Table 1 summarizes the situation existing prior to the publica-

tion of the work of the present Commission.

Prone Pressure Group

Seven out of sixteen firms rely upon manual methods to the exclusion of apparatus. The statements made are of interest:

Chicago.—"The only equipment provided is an oxygen tank to use with the artificial respiration in case it is needed. This practice has been established because a study of the pulmotor reports used by this office prior to 1915 did not show satisfactory results."

Atlanta.—"We have a pulmotor but have discarded use of this. We use the prone pressure method."

Newark.—"The Public Service Gas Company has become satisfied that the Prone Pressure Method of Resuscitation is superior to any requiring mechanical appliances."

Portland.—"We have used the Pulmotor in a limited number of cases but our experience has not been sufficient to arrive at any definite opinion as to its merits or demerits. We are inclined to believe, however, judging from our experience, that the Prone method of resuscitation is superior to the use of the Pulmotor or other similar appliances on the market."

St. Louis.—"We formerly had a number of lungmotors, and still have them but are not using them. We have discarded their use due to the delay which usually follows in the lungmotor reaching the scene of the accident promptly, and which is so essential to rescue work. We are thoroughly convinced the Prone Pressure Method of resuscitation is the best method, for the reason fellow workmen can, without any delay, or without waiting for mechanical equipment, immediately start to work on the victim. The use of mechanical equipment requires a trained operator, and also requires the equipment itself be kept in a 100 per cent. condition at all times, and we are advocating the use of the Prone Pressure Method in cases of electric shock, as well as gassed cases."

Milwaukee.—"This company does not maintain a rescue squad though we do own and keep at convenient locations two pulmotors and three lungmotors. We, however, have never used any one of these machines in the several years that they have been in our possession. . . . There is so much conflicting testimony that we have been very

TABLE 1.—SUMMARY OF THE IMMEDIATE METHOD OF RESUSCITATION EMPLOYED BY A GROUP OF REPRESENTATIVE GAS PRODUCERS IN THE UNITED STATES

Prone Pressure Method (No Apparatus Used)	Lungmotor	Pulmotor
1. The Peoples Gas Light and Coke Company of Chicago	1. The Denver Gas and Electric Light Company	1. The Consolidated Gas Electric Light and Power Company of Baltimore
2. The Georgia Railway and Power Company	2. The Detroit City Gas Company	2. The Boston Consolidated Gas Company
3. The Milwaukee Gas Light Company[1]	3. The New Haven Gas Light Company	3. The Brooklyn Union Gas Company
4. The Public Service Gas Company of Newark		4. The Denver Gas and Electric Light Company
5. The Portland Gas and Coke Company		5. The New Haven Gas Light Company
6. The Laclede Gas Light Company of St. Louis		6. The Providence Gas Company
7. The Southern California Gas Company[2]		7. The Consolidated Gas Company of New York
		8. The United Gas Improvement Company of Philadelphia

[1] Owns both lungmotor and pulmotor but has never used them.

[2] Possesses pulmotor but has never used it.

loath to put the equipment into use on our own responsibility.''

Lungmotor Group

Denver.—''In all our plants, general office, and in the safety department, we have both the pulmotor and lungmotor, oxygen tanks, and special breathing devices. Our men are instructed to never use them except as a *last resort.* Our teams and men have been taught the prone pressure method and I fully believe that if this method fails to revive a patient, all the artificial devices will be of no avail. I have no faith in the lungmotor or pulmotor, but for the moral effect I feel that it is wise to have them.''

Detroit.—''The Detroit City Gas Company makes use of rescue crews, the members of which are trained in the company's School of Instruction in the mechanical handling of gassed cases and in the providing of proper ventilation, etc.; also, in the use of the Schäfer method of artificial respiration, the use of the lungmotor and its accessories, in the administration of stimulants, and in diagnosing the effects of treatments administered. . . . We believe that the lungmotor is very efficient as a means of resuscitation. Over a period of two years, not a single case has been lost where life was found to exist when we took charge of the subject.''

Beginning in January, 1921, this company has kept a record of the cases of gas poisoning which it has cared for. The list consists of fifty-six cases. Table 2 indicates the character of the respiration in these patients when relief measures were instituted. In two cases character of breathing was not given. Of the cases not breathing when first seen, all three were pronounced dead by a physician either immediately or within thirty minutes.

Table 3 shows at a glance the treatment given under the varied conditions of respiration which existed when the patients were first seen. If gassed patients are not breathing, they are dead or very nearly so, and the wisdom of relying upon the prone pressure method of artificial respiration without the necessity of waiting for instruments is at once apparent. The gassed patient who has stopped breathing is in even worse condition than the patient suffering from electric shock, since he has been subjected to a considerable period of anoxemia prior to actual cessation of respiration, and his heart is in no condition to stand further strain. Table 3,

TABLE 2.—CHARACTER OF RESPIRATION IN FIFTY-FOUR CASES OF GAS POISONING WHEN FOUND BY RELIEF CREWS OF THE DETROIT CITY GAS COMPANY

Not Breathing	Slight or Difficult Breathing	Excessive Breathing	Normal Breathing
3	14	21	16

however, brings out the fact that most patients poisoned by illuminating gas are breathing when first seen. No patient who breathes naturally needs or should be given artificial respiration either by apparatus or manually. Apparatus is likely to oppose the natural movements rather than to assist them, which is not the case with the manual method. But even this method is contraindicated when the subject is breathing spontaneously. The object to be aimed at is the displacement of carbon monoxide from the blood through the mass action of increased oxygen concentration in the lungs.

The wisdom of the oxygen carbon-dioxide inhalations recommended by Henderson and Haggard in the first report of the committee is more than ever clear. The best chance for recovery of the fourteen patients breathing slightly or with difficulty is in natural or in rather deep breathing, with opportunity to get plenty of oxygen. Such a situation

is provided with greater certainty by means of oxygen carbon-dioxide inhalations than by any measures entailing positive pressure ventilation.

A final point of interest is found in the number of patients who were breathing either excessively or naturally. These are cases of early or slight poisoning, yet it will be seen that the lungmotor has been used in six of them, a procedure which has no logical justification. The existence of a period of excessive breathing is an interesting confirmation of the experiments of Henderson and Haggard presented in the first report of the Commission.

In twenty-one of the fifty-six Detroit cases the patients were unconscious when first seen, and certain of them were sent to hospitals. In four cases the breathing is described as *hard,* which means obstructed. All of these points are of importance to us. The unconscious patient, even though he may be able to breathe normally, is less able than is the conscious individual to protect himself against the possibility that mucus, saliva, vomitus, or blood may pass down the trachea and into the lungs. The frequency of pulmonary complications in gassed cases forms the second part of this report and the possible relation of positive ventilation to such complications is discussed.

New Haven.—The New Haven Gas Light Company instructs a fairly large group of employees in the prone pressure method of resuscitation and also possesses both a pulmotor and a lungmotor. In regard to the condition of gassed cases when first seen, the following statement is made: "During twelve years' active service with gangs of men engaged in laying gas mains and services, there have been probably only five or six cases where the patient did not recover consciousness in less than five minutes. The largest number of cases (numbering possibly two hundred) have returned to consciousness in from one to three minutes. My understanding of this fact is that the patient has been more suffocated by the absence of oxygen than poisoned by the carbon monoxide of the manufactured gas, and as soon as removed from a gaseous atmosphere, if respiration had not been entirely suspended, natural breathing was sufficient to return the patient to normal condition."

The reasons given for utilization of the pulmotor and the lungmotor are: "The pulmotor was chosen because it provided an apparatus to use in extreme cases where respiration had practically been suspended, that would draw out of the lungs what air or gas was in them, and would put into the lungs air that had been enriched with additional oxygen. It seemed to function under a pressure that (to the layman at least) was not great enough to destroy the lung tissues. Later when the lungmotor was developed, it was purchased as an additional equipment, that probably was better than the pulmotor on the ground that the quantity put into and taken out of the lungs could be increased or decreased (within reasonable limits) to suit the lungs of the patient."

TABLE 3.—CHARACTER OF TREATMENT IN FIFTY-FOUR CASES OF GAS POISONING REPORTED BY DETROIT CITY GAS COMPANY

Not Breathing	Slight or Difficult Breathing	Excessive Breathing	Normal Breathing
3	14	21	16
Lungmotor in 2.	Lungmotor in 13. Oxygen inhalations in 1.	Lungmotor in 4. Oxygen inhalations in 17.	Lungmotor in 2. Oxygen inhalations in 14.

The Pulmotor Group

Eight firms possess and use the pulmotor. Upon reading their experiences with the instrument, one obtains the impression that the original purchases were made some time ago when the mechanical ingenuity of the apparatus, coupled with a most effective advertising campaign, seem to have recommended the pulmotor very widely; and that

its use at the present time depends largely upon the demand of the public for the instrument—a demand which, in turn, is fostered by the willingness of the press to print any item of news to which the word *pulmotor* is attached. None of the material received contained data demonstrating an efficiency for the pulmotor unattainable by the simple manual method of artificial respiration. The following statement will serve to summarize the general attitude of pulmotor users toward the subject.

Philadelphia.—"We consider the Schäfer Manual Prone Pressure Method as now taught superior to any method involving mechanical apparatus, but have not had any experience to indicate that the latter should be entirely done away with."

Summary of Section I

The first section of the report may be summarized as follows:

1. Gas companies throughout the country are making earnest endeavor to provide the best means of resuscitation known to them.

2. Seven firms employ the Schäfer prone pressure method alone. Three employ the lungmotor and eight the pulmotor (two of these firms using both instruments). Of those using the prone pressure method, three have discarded mechanical devices for artificial respiration.

3. The experience of the Detroit City Gas Company indicates that in most cases of gas poisoning the patients are breathing when first seen and that a large percentage are unconscious.

4. These facts indicate the utility of the oxygen carbon-dioxide inhalations recommended by Henderson and Haggard in the first report of the Commission. This method of treatment induces deeper breathing and avoids the possibility of forcing fluid into the lungs and so giving a basis for a possible bronchopneumonia. Inhalation of oxygen alone has rather wide employment among the gas companies and can be commended.

5. The fact, as indicated by the Detroit City Gas Company records, that the most severely gassed patients are usually taken to a hospital indicates the necessity for an examination of hospital records in order to get data upon the final outcome of gassing and, in particular, upon the frequency of pulmonary complications—a point which bears upon the type of artificial respiration to be advised.

Section II. The Eventual Course of Patients Poisoned by Carbon Monoxide

Seriously gassed patients do not present immediate problems in regard to resuscitation when they finally arrive at a hospital. At this time they have practically always begun to breathe, and they are brought in for care during recovery from a severe experience. It happens, however, that the subsequent course of such cases has a possible relation to the type of resuscitative treatment applied by rescue squads when the patients are first seen.

The literature upon carbon monoxide poisoning contains many references to pneumonia as a sequel, and to the existence of râles in the chest and of pulmonary edema as immediate accompaniments of severe gassing, and especially of gassing which has occurred slowly. There are, however, no statistical data upon the frequency with which excess moisture is found in the respiratory passages and deep in the lungs of patients poisoned by gas. If it should prove to be the case that gas poisoning is frequently accompanied by moisture in the

respiratory passages, the evidence might have direct bearing upon the type of artificial respiration to be employed when the patients are first seen. An examination of the literature has not disclosed experiments upon the question whether positive ventilation can force infected material down the trachea and into the depths of the lungs. If this should be the case, and it is a subject for experimentation by the Commission at the present time, the bearing upon the use of apparatus such as the pulmotor and lungmotor is obvious. Both of these instruments drive air into the lungs and whether they operate with a sufficient degree of force to carry infected material into the alveoli to form eventual patches of bronchopneumonia, merits investigation.

Examination of the literature discloses the fact that cardiac failure and particularly failure of the right side of the heart, accompanied by pulmonary edema, is frequently the cause of death or of serious danger in gassed patients. If apparatus for artificial respiration is used which is capable of increasing intrapulmonic air pressure to an inordinate degree, it may well be possible at the height of the inspiratory stroke to compress the alveolar capillaries and thus raise the blood pressure in the pulmonary circulation. The unfortunate effect of such a situation upon a right ventricle already in a precarious condition is obvious. Fortunately, this objection to positive ventilation in illuminating gas poisoning is one which can be answered by experimentation upon animals, and animal experiments in which are utilized familiar types of artificial respiration apparatus, such as the lungmotor and the pulmotor, are, therefore, being undertaken and will be made public in a later report.

The literature upon gas poisoning lacks statistical data upon the frequency of bronchopneumonia as a sequel and upon the existence of lung findings in general. Believing the best source of such data to be hospital records, we have made an examination of the records of gassed patients in nine hospitals in Boston, New York, and Philadelphia. The total number of cases covered in this investigation is 860. The distribution, together with the years covered, is given in Table 4. The data from the three cities were gathered by different individuals and the points covered were kept as simple as possible. The hospitals providing the material were:

Boston.—Boston City Hospital.

New York.—Bellevue Hospital.

Philadelphia. — Pennsylvania Hospital; University Hospital; Episcopal Hospital; Presbyterian Hospital; Hahnemann Hospital; Jefferson Hospital; Polyclinic Hospital.

To anyone accustomed to the elaborate records now available in our better hospitals upon such subjects as chronic cardiac or renal disease, the brief and inconclusive statements which characterize the hospital records of gas poisoning come as something of a shock. Occasionally full notes are found, but ordinarily the patient recovers or dies without arousing significant interest. That gas poisoning in man may be a profitable field for medical investigation does not seem to have been considered, and this in hospitals where less common and less dangerous diseases are receiving large amounts of study and attention. On account of the meager records available, we have confined our final analyses to a small number of the most pertinent items. A brief inspection of Table 4 will serve to show that the items chosen do not, in the main, require great subtlety

of diagnosis or great effort in recording. Where pneumonia has occurred, there has usually been a lapse of several days following admission to the hospital. The records improve in such cases and follow the usual trend that one expects in the description of an acute infection.

The facts presented in Table 4 are strikingly uniform and bear upon the immediate problem of resuscitation in the following items:

1. 59.8 per cent. of the gassed patients were unconscious on admission to the hospital or were reported as unconscious when found.
2. 44.4 per cent. were breathing rapidly. Only in rare cases was the breathing very slow.
3. The admission pulse rate was high, averaging 104 for the entire series of cases.
4. The records show an average of 6.4 per cent. of patients frothing at the mouth; 17.4 per cent. with râles in the lungs; and 4.5 per cent. with pulmonary edema.

These findings were undoubtedly present in very large part when the patients were first picked up by rescue squads. It thus becomes at once apparent that resuscitative measures in gas poisoning must, in large measure, be applied to unconscious patients who are breathing rapidly, who have rapid hearts, and who, in a large percentage of cases, have excess fluid in the respiratory tract. We have already commented upon the possible dangers of positive ventilation of the lungs in conditions such as these figures show to be very frequent in gas poisoning.

It will be noted that the percentage of pneumonias following gas poisoning is not high. The fact that fatal cases almost invariably show a rise in temperature makes it seem probable to us that some degree of bronchopneumonia must be present in nearly all patients who do not succumb immediately following their exposure to gas. The pneumonia in such instances is probably only a contributory cause of death, fatality being due, in the main, to cardiac and central vasomotor failure. Our table, therefore, tells the story of the severe and unmistakable pneumonias alone. Only by careful autopsy reports can the full quota of pneumonias be ascertained.

A comparison of the figures obtained in our study with the findings reported by other observers is of interest. Gilman Thompson (2) in 1904 made an analysis of ninety cases of illuminating gas poisoning occurring in New York City, and Lämpe (3) in 1921 reported a series of 205 cases treated at the Dresden-Johannstat municipal hospital during the years 1912 to 1921. Only patients sufficiently gassed to become unconscious were included in these two studies. The mild cases were thus eliminated, and a somewhat more serious picture of gas poisoning is presented than the figures given in Table 4 suggest. Table 5 gives an analysis of the findings in the 514 unconscious patients in our series of cases and may, therefore, properly be compared with the observations which were reported by Thompson and Lämpe.

The mortality in Thompson's series was 18.8 per cent.; in Lämpe's, 17.6 per cent.; in ours (unconscious patients only), 22.6 per cent. The first 54 of Lämpe's cases, occurring during 1912, 1913, 1914 and 1915, had a death rate of only 5.6 per cent. During the 1916 to 1921 period the mortality rose to 21.8 per cent. The percentage of carbon monoxide in the illuminating gas in Dresden during this same period increased as follows: 1913, 8.4 per cent.; 1914, 10.8 per cent.; 1915, 12.2 per cent.; 1916, 14.3 per cent.; 1917, 16 per cent.; 1918, 18.4 per cent.; 1919, 21.6 per cent.

TABLE 4.—CASES OF ILLUMINATING GAS POISONING IN BOSTON, PHILADELPHIA, AND NEW YORK

	1906-1909 1918-1921	1908-1921	1904-1917 1922	Percentage			Summary
	Boston	Philadelphia	New York City	Boston	Philadelphia	New York City	Boston, New York and Philadelphia
				%	%	%	%
Total number of cases	235	220	405	—	—	—	—
Average age on admission	41	39	39	—	—	—	—
Deaths	32	26	67	13.6	11.8	16.5	14.5
Number unconscious	143	142	229	60.4	64.6	56.5	59.8
Number frothing at the mouth	14	13	28	6.0	5.9	6.9	6.4
Number respiration 26 or below	54	117	224	43.2	59.1	57.9	55.6
Number respiration above 26	71	81	163	56.8	40.9	42.1	44.4
Average pulse on admission	108	102	104	—	—	—	—
Average temperature on admission	98.4°	98.4°	99.1°	—	—	—	—
Average last temperature recorded before death	—	104.4°	103.6°	—	—	—	—
Lung findings:							
Râles	45	24	73	19.1	13.6	18.0	17.4
Edema	8	12	17	3.4	6.8	4.2	4.5
Pneumonia	7	7	34	3.0	4.0	8.4	5.9
Total with abnormal moisture in respiratory tract	60	43	124	25.5	24.4	30.6	27.8
Abscess	—	1	—	—	—	—	—

TABLE 5.—CASES OF ILLUMINATING GAS POISONING IN BOSTON, PHILADELPHIA, AND NEW YORK: UNCONSCIOUS PATIENTS ONLY

		1906-1909 1918-1921	1908-1921	1904-1917 1922	Percentage			Summary
		Boston	Philadelphia	New York City	Boston	Philadelphia	New York City	Boston, Philadelphia and New York City
					%	%	%	
Total number of cases		143	142	229	—	—	—	514, total cases
Deaths		29	25	62	20.3	17.6	27.1	22.6%
Frothing at mouth		13	10	26	9.1	7.0	11.4	9.5%
Respiration on admission	26 or below	30	70	100	35.7	53.0	46.5	46.4%
	above 26	54	62	115	64.3	47.0	53.5	53.6%
	av. per min.	30	27	28	—	—	—	28, av. per min.
Pulse on admission	below 100	18	54	53	21.2	41.5	26.2	30.0%
	100-120	49	55	109	57.6	42.3	54.0	51.1%
	above 120	18	21	40	21.2	16.2	19.8	18.9%
	av. per min.	110	103	107	—	—	—	107, av. per min.
Temperature on admission	below 97°	14	21	42	16.3	15.8	18.9	17.5%
	97°-99°	48	72	75	55.8	54.1	33.8	44.2%
	above 99°	24	40	105	27.9	30.1	47.3	38.3%
	av.	98.2°	98.4°	98.9°	—	—	—	—
Lung findings	Râles	30	18	52	21.0	15.7	22.7	20.5%
	Edema	8	12	15	5.6	10.4	6.5	7.2%
	Pneumonia	6	7	33	4.2	6.1	14.4	9.4%
	Total with moisture	44	37	100	30.8	32.2	43.6	37.2%

This increase in the carbon monoxide content of the gas offers a very probable explanation of the mortality rise.

Of our unconscious patients, 53.6 per cent. were breathing at a rate above 26 per minute, the average respiration rate for the entire group being 28 per minute. Thompson reports that in his patients the respiration rate averaged about 30 per minute. In Lämpe's cases the average range was from 24 to 32, the rate being "seldom quite normal."

Thirty per cent. of our unconscious patients had a pulse rate, on admission to the hospital, of below 100 per minute; 51.1 per cent. had a rate of between 100 and 120; 18.9 per cent. had a pulse rate of over 120; the average rate was 107 per minute. Thompson reports marked acceleration of the pulse. The count was seldom below 120 and frequently reached 136 to 140. Lämpe reports a pulse rate of 140 and above in the severe cases, and a tachycardia (no rate specified) in the less serious ones.

Thompson observed an elevation of the temperature in almost all of his patients. In eight cases there was a preliminary fall. Lämpe reports that in most cases the temperature did not rise above 38° C. (100.4° F.) though occasionally it reached 40° C. (104° F.). Of our patients, 17.5 per cent. were admitted with a temperature below 97° F.; in 44.2 per cent., the admission temperature ranged between 97° and 99°; in 38.3 per cent., the temperature was above 99°.

In discussing the lung findings, Thompson says, "Occasional sequelae are bronchitis, broncho and lobar pneumonia." Later he says, "It was a surprise to the writer that bronchopneumonia, or other definite pulmonary lesion, is not more constantly an outcome of fatal gas poisoning, but in only three of the twelve autopsies was bronchopneumonia observed." The lung findings, however, in the twelve autopsies which he reports showed normal lungs in only 25 per cent. of cases. The autopsy findings were as follows: normal, 2 cases; normal, except for a few miliary tubercles, 1 case; congestion (complete), 1 case; congestion and edema (complete), 3 cases; congestion and edema in partial areas, 5 cases; emphysema (partial and compensatory), 4 cases; atelectasis (partial), 2 cases; bronchopneumonia, 3 cases. There is no mention of physical examinations of the lungs of patients who recovered, so we have no means of judging the incidence of transient lung changes in Thompson's cases.

The lung findings reported by Lämpe were the frequent occurrence of bronchitis, 1 case of edema (with frothy sputum), 10 cases of bronchopneumonia, 2 cases of pleuritis without bronchopneumonia, 7 cases of hypostatic pneumonia, 4 cases of aspiration pneumonia, and 2 cases of gangrene of the lungs—a total of 12.7 per cent. of cases with lung involvement, exclusive of the cases of bronchitis.

Of our unconscious patients, 20.5 per cent. had râles; 7.2 per cent., edema; and 9.4 per cent., pneumonia—a total of 37.2 per cent. with abnormal moisture in the lungs.

Summary of Section II

An examination of hospital records in three representative eastern cities shows:

1. An average death rate of 14.5 per cent. of cases which have passed beyond the stage of first-aid treatment and have become hospital patients.
2. A high average pulse rate.
3. A group comprising 27.8 per cent. of the total number studied who have undue moisture in the lungs.

Conclusions

1. No evidence has been obtained from representative gas companies which indicates that either the lungmotor or the pulmotor is superior to the manual prone pressure method of artificial respiration.

2. The evidence obtained leads to the conclusion that if apparatus is to be employed to supplement this simple method of artificial respiration, it should be in the form of some device to provide inhalation of oxygen and carbon dioxide as recommended by Henderson and Haggard.

3. Evidence gathered from hospital records indicates that in gas poisoning any method of artificial respiration which drives air by positive pressure into the lungs may be a source of danger to the patients treated. Devices such as the pulmotor and lungmotor operate in this way and consequently would seem to require further investigation before being recommended for use in gas poisoning.

4. Owing to the fact that other physiological factors enter the problem of artificial respiration in gassing, the Commission has undertaken a series of experiments upon further phases of the problem and will offer final recommendations at a later date. At the present time, the best directions for rescue crews are those already given by Henderson and Haggard—namely, immediate use of the Schäfer prone pressure method of artificial respiration in non-breathing cases, supplemented as soon as possible by oxygen carbon-dioxide inhalations given through a suitable inhaling device.

BIBLIOGRAPHY

1. Henderson, Y., and Haggard, H. W.: The Treatment of Carbon Monoxid Asphyxia by Means of Oxygen+CO_2 Inhalation. Jour. Am. Med. Assn., 1922, *79*, 1137.
2. Thompson, W. G.: Illuminating Gas Poisoning: A Clinical Study of 90 Cases. Med. Rec., 1904, *66*, 41.
3. Lämpe: Beitrag zur Kenntniss der Kohlenoxydgasvergiftung. Zentralbl. f. Gewerbehyg., 1921, *9*, 281.

INDUSTRIAL MEDICINE IN 1922*

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INDUSTRIAL medicine has now been practiced in the United States about ten years. At first a new field not thoroughly understood, it has gradually taken shape until at present the term has a distinct meaning, and the industrial physician a specific classification.

During the formative period a number of what were originally fundamental ideas have changed and methods at first unnecessarily elaborate have been simplified. It seems that this is a good time to review the present situation and to try to outline the beliefs and practise of today. It is generally recognized that the success of an industrial medical department depends largely upon two things: the character and training of the physician, and the co-operation of the management.

The Conference Board of Physicians in Industry has recently defined the industrial physician:

> The physician in industry is one who applies the principles of modern medicine and surgery to the industrial worker, sick or well, supplementing the remedial agencies of medicine by the sound application of hygiene, sanitation, and accident prevention; and who, in addition, has an adequate and co-operative appreciation of the social, economic and administrative problems.

Thus, it is now believed that the difference between a physician in general practise and an industrial physician consists in the latter's appreciation of the problems of industry and the application of the art and science of medicine and surgery to these problems. He is more truly a physician in industry than an industrial physician.

Co-operation of the management means active participation in the medical department plus interest in its aims and accomplishments. The management should use the department as freely and willingly as the worker. An intelligent review of the accomplishments of the medical department will determine its value to the organization. That the value is now recognized is shown by the fact that "during the industrial and business depression, through which the country has just passed, there was ample opportunity for considering the value of various non-productive industrial activities, and the fact that the medical department in industry has retained its standing and importance to a relatively higher degree than have many other non-productive activities, is evidence of the value of the work" (1).

The basic activities of the medical department have always been:

1. Physical examination of applicants for employment.
2. Treatment of accidents and sickness occurring within or outside the factory.
3. Preventive medical measures.
4. Supervision of sanitation.
5. Nursing service.

The present methods of handling each of these will be considered.

Physical Examination of Applicants for Employment.—It is now recognized that whenever possible the examination should be made before employment at the factory, and by a physician. The

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length of time allotted to each examination is from six to fifteen minutes. The object of the examination is to determine whether the applicant is physically suitable for the work to which he is assigned by the employment department. If he is not, work in some suitable department should be provided if such work is available, unless the physician considers the employment of the individual a danger to himself, to others, or to property. If for the foregoing reasons the applicant is refused employment, the reason for his rejection should be explained to him fully and advice given him.

The physical examination is made for the purpose of discovering defects which contraindicate employment or which require placement. Thus special attention has been drawn to certain conditions. Watson (2) has listed these as follows:

(*a*) Active pulmonary tuberculosis.

(*b*) Cardiac disease with potential or established decompensation.

(*c*) Active or chronic venereal disease.

(*d*) Acute contagious disease.

(*e*) Chronic progressive disabling disease, such as Bright's disease and diabetes.

(*f*) Potential and active focal infection.

(*g*) Defective vision and hearing of a degree incompatible with the requirements of a given industry.

To this list should be added chronic disease of the joints, particularly the joints of the spine and lower extremity.

The following conditions previously considered dangerous are now considered safe if the worker is properly placed and watched:

(*a*) Hernia, if held by a truss (3).

(*b*) Varicose veins, if ulcer is absent.

(*c*) Varicocele.

(*d*) Flatfoot, if without symptoms.

(*e*) Deafness, except in special departments.

(*f*) Defective vision, except in special departments.

(*g*) Arteriosclerosis.

(*h*) Endocarditis unaccompanied by marked myocarditis (4).

Criticism has been made that six minutes is too short a time to be allowed for examination; thus "five or six minutes may be enough for an examination conducted under rigid military discipline; but such a discipline will not make the doctor and his assistants popular with the worker; it will not secure a desire on his part to seek advice and submit voluntarily to further examination should the state of his health require it" (5).

This criticism has not been borne out by experience. The reason that the examination can be made rapidly is because the time of undressing is eliminated and all examining apparatus and instruments are at hand. Unless applicants receive quick and accurate service, the work of the employment department is retarded and the applicants themselves complain. Accurate work can be done in the time indicated, and employees do return voluntarily for further examination and treatment where this is needed.

Where a serious defect is discovered and the applicant placed at suitable work, he is reexamined at intervals, his condition is recorded, and advice is given. In many factories this reexamination is very complete and takes about one-half hour, a special record being filled out. The types of patients receiving special attention are those with cardiac disease, nephritis, arrested pulmonary tuberculosis, and hernia. A periodic examination is also given to workers who are exposed to special

health hazards or who work in poisonous processes.

Treatment of Accidents.—The first-aid treatment once so widely advocated and stretched into redressings has been simplified and confined to narrow limits. This has increased its efficiency. "First aid means the immediate treatment of personal injuries by any one other than a doctor" (6). It is carried on by a non-medical, trained person who is near at the time of the accident. It is therefore common in large factories to have in each department where there is hazard a group of trained workers who are capable of carrying out such immediate treatment as is necessary.

According to Shoudy (7), there are four cardinal points to be taught in first aid, to which other things may be added as necessary. These points are:

1. Shock—its symptoms and treatment;
2. Hemorrhage—how to control by direct pressure, seldom by tourniquet;
3. Asphyxia—its causes, symptoms and treatment; artificial respiration by the Shaeffer prone pressure method only;
4. Transportation—careful handling of the injured in a minimum of time, so as not to cause pain or further trauma, is one of the most important things taught first aid classes.

In most factories employing over 150 employees there is now a dispensary with a trained nurse or doctor in attendance, so that first aid consists in doing only what is immediately necessary and then rapidly transporting the patient to the dispensary where proper treatment may be applied. The day when the "first aid man applied antiseptics to wounds and removed foreign bodies from eyes has passed."

In the majority of factory medical departments the treatment of all open wounds has been standardized. This treatment consists in flushing or washing the wound with gasoline, and then applying tincture of iodine either full or half strength by sterile cotton applicator or by medicine dropper. In some factories a soap and water cleansing, followed by the application of Dakin's solution or Dichloramin-T., is preferred; as it is more complicated, however, and requires in the case of Dakin's solution a moist dressing, which may irritate the skin, the gasoline and iodine sequence is preferred. In the treatment of fractures, the Thomas type of splint, such as is used in the United States Army, has come to be the standard transportation splint.

The number of solutions used in factory dispensaries has also been greatly reduced, and it is hoped that soon one or two standard solutions for wet dressings will be all that are necessary.

It will be seen from the foregoing that the present practise is to reduce and simplify wherever possible, and a strong effort is being made to standardize treatment wherever this can be safely done.

Along with reduction of solutions and apparatus, there has been a move toward grouping treatments. For example, all clean hand and arm injuries are treated at one part of the dispensary, all infections (boils, etc.) at another, and all eye cases in a special eye room. This is called the unit method of treatment, and is in force in the dispensaries of all large factories.

By these newer methods it has been possible to increase the rapidity of treatments and to reduce the waiting period of those requiring dressings.

Diagnosis and Treatment of Sickness.—Every large factory is a community in itself and presents the public health problems of a small village. Epidemics must be prevented, sanitation must be kept at a high standard, and industrial disease due to specific poisons must be eliminated. As a result of these needs,

industry requires a certain amount of public health knowledge and activity in its medical department. Instead of merely diagnosing and treating individual cases the health condition of the factory as a whole is considered, and morbidity statistics are kept and reviewed at frequent intervals. In some factories a health insurance plan is carried out, whereby a portion of the employee's wages are paid to him when he is out sick. A system of this kind acquires most accurate records and allows the physician in charge to analyze the causes of absenteeism and to plan preventive measures when these are possible.

Diagnostic methods have been more fully applied each year. While few factories have elaborate laboratories, most factories have laboratory equipment of some sort and an increasing number have their own X-ray outfits. The diagnosis of obscure cases is usually referred to the patient's physician or to a general hospital, but many rather difficult diagnoses are now being accurately made in industrial medical departments.

Treatment of sickness still is very minor. All the emphasis is being placed on prevention, and efforts are being made to check beginning colds, stomach disorders, and similar conditions which may later cause severe sickness. The following up of chronic heart, kidney and goiter cases is another function which is being elaborated upon.

The plan of sending all really sick employees to their family physician or to a general hospital is still adhered to, and many more patients are being referred to specialists for treatment of the eyes, ears, nose or throat than formerly. Incidentally, the general and special practitioner is co-operating with the industrial physician more freely each year. While some factories have worked out special treatments for common minor diseases such as coryza, no one treatment for any condition has been successful enough to become standardized.

Preventive Medical Measures.—These have been discussed in the preceding sections.

Sanitation.—Nothing particularly new has been added to sanitary inspection, except that more strict standards are being required by states, and various engineering societies have studied lighting and ventilation, particularly lighting. The result has been the production of an American Standard Industrial Lighting Code (8). This is the result of long and painstaking work and has been officially approved as an "American Standard" by the American Engineering Standards Committee. It has been submitted to, and approved of, by thirteen national organizations, and is the basis of a proposed lighting code advocated by the Department of Labor and Industries of the state of Massachusetts. Similar codes of industrial ventilation and exhaust systems have been published by the National Safety Council (9). Thus, there is a continuous process of standardization of sanitation proceeding, and manufacturers are interesting themselves in it more each year.

The industrial physician is constantly presenting constructive suggestions before the management so that the general sanitation of factories is improving.

Nursing Service.—The industrial nurse has become a *sine qua non* in industrial medicine. Both as a dispensary assistant to the doctor and as a visiting nurse, her value is now definitely recognized. In some states every factory employing more than a certain small number of employees must provide a small dispensary with a trained attendant. So great has been the call for nurses in in-

dustry that in some communities the regular nursing has suffered.

The visiting nurse combines social service work with nursing visits, and acts as a connecting link between the factory and the worker's home.

The response of workers to the work of the industrial medical department has been most encouraging. Physical examinations are seldom refused, and in a medical department which has been in activity for several years, the dispensary is in continuous use. A factory with 2,000 employees will show an average of seventy-five visits a day. This alone demonstrates the need for medical service and the worker's appreciation of it.

Considering the recent business depression with its economies and reductions of working force, it is remarkable that industrial medical departments were not more affected. With increasing business there is every indication that industrial medical departments will continue to develop and become even more valuable to both worker and management than they have been in the past.

BIBLIOGRAPHY

1. The Physician in Industry: A Symposium. Nat. Indust. Conference Board, Special Rep. No. 22, June, 1922, p. iii.
2. Watson, C. H.: Physical Examinations: A Résumé. *Ibid.*, p. 22.
3. McCurdy, S. M.: Hernia from Compensation Standpoint. *Ibid.*, p. 78.
4. Clark, W. I.: Our False Standards of Disability in Industry. Nation's Health, 1921, *3*, 564.
5. Clark, W. I., Jr.: Health Service in Industry. Reviewed in Survey, 1922, *48*, 629.
6. Outline of Lecture on First Aid. National Safety Council for Supervisors.
7. Shoudy and Colcord: Standards of First Aid. Rep. Comm. Am. Assn. Indust. Physicians and Surgeons, 1922.
8. Code of Lighting: American Standard. Illuminating Engin. Soc., 1921.
9. Exhaust Systems. Nat. Safety Council, Safe Practices No. 32. Industrial Ventilation. Safe Practices No. 37.

THE VENTILATION OF ENGLISH FACTORIES AND WORKSHOPS IN HOT WEATHER*

T. C. Angus, D.F.C., Graduate I.E.E.

A LARGE rubber manufacturing firm with an expanding trade during the war moved a great part of its works from old premises in a town to newly erected buildings in the open country. These new buildings, for the most part single story structures of the "saw tooth" type, were more roomy, better lighted and altogether more convenient than the old factory. As in the old buildings, however, many parts of them became far too hot in the summer time—so hot, in fact, that it was believed that the general health and efficiency of the workers were impaired, and that the labor turnover was made unduly high, many workers whose training had cost time and money having to leave because they were unable to bear the conditions.

It became the writer's task to investigate these conditions and by applications of the principles of Dr. Leonard Hill, with whom he has the good fortune to work, to indicate their causes and to suggest practical remedies.

Description of the Buildings

The buildings are steel constructions with brick ends and sides, the "saw tooth" roofs having alternate slopes of glass (facing north) and double roofing of asbestos sheets covered with felt with air-space between. When these buildings were first erected they had no windows at the ends or the sides, and no openings were provided save the necessary doors and four 12-inch ventilation holes in the roof to each space enclosed between any four stanchions in the buildings. These spaces had an approximate cubic content of 10,760 cubic feet, so that the 12-inch holes gave to the entire buildings a natural ventilation figure of 0.292 square feet of opening per thousand cubic feet of enclosed space. This natural ventilation figure was found to be useful in estimating the probable effect of different windows and lights, and will be referred to again; 0.292 is an extremely low value.

All the buildings can be effectively heated by an exhaust steam system, the pipes for which are carried along under the roof at a height of 11 feet and 6 inches above the floor.

Nature of the Work of the Factory

Most of the manufacturing processes used in these works call for no great physical effort, and can be carried out under ordinary conditions of heat, light and air, but two particular operations—curing and solutioning—require the workers to be exposed to high temperatures.

Curing and Solutioning.—In the curing or moulding shops the goods are placed in large receptacles or pans, into which live steam is admitted for the period required. The steam is then blown off and the pan opened to remove the cured articles. In this way a large amount of hot air and water vapor is released into the air of the department.

In the solutioning rooms a high temperature has to be maintained in order to prevent the moisture in the air from condensing on the solutioned surfaces of the goods, which may be cooled to the

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dew-point of the air by the evaporating solvent. The only practicable means that has so far been found of preventing this condensation, the occurrence of which spoils the process, is to raise the temperature of the air in the shops where the solutioning is done.

Previous Attempts at Improving Conditions

The management of this factory was anxious to discover some means by which conditions might be improved in hot weather, and in one of the departments experiments had been made with an air trunk or blast system, before the writer undertook the ventilation work. The effects produced by this system were as follows:

In a department of about 129,100 cubic feet content, where nearly all the work done produced no heat or effluvia, three 12-inch fans delivered air into 9-inch sheet iron trunks which were carried along the walls on either side of the building at a height of about 8 feet above the floor. At short intervals along these trunks long, thin horizontal slots were formed, through which the air was intended to flow down and out at an angle of 45° toward the floor, while in a direction perpendicular to the axis of the trunk.

The air was drawn in from under cowls on the roof, and before entering the trunks was passed through heaters that could be supplied with exhaust steam in cold weather. As the static pressure in these trunks was extremely low, and the energy of the air was almost entirely kinetic, the air in the greater part of the building was unaffected, the drafts produced being only very local, and in a line almost parallel with the direction of the trunk. Where currents from either fan met and opposed each other there was a powerful local draft.

The layout of this department with the positions of the trunks and the directions and relative velocities of the air currents is shown in Figure 1.

Air Changes or Renewals Produced.—It was found that in the above department each of the three 12-inch fans, used to supply air to the trunks and similar fans, on test, delivered not more than 1300 cubic feet of air per minute. This should change the air $\frac{3{,}900 \times 60}{129{,}100} = 1.8$ times per hour.

Thompson gives the air changes per hour desirable in textile mills as 4, and in foundries as 3. Allen and Walker give the cubic feet of air required in workshops per occupant per hour as from 600 to 2,000. By Thompson's standard the fresh air supplied by these fans is quite insufficient, and by Allen and Walker's it is more than enough, there being only about fifty workers employed at one time in this building. If we consider that each worker requires 1,000 cubic feet per hour in this clean shop, the total fresh air required per hour = 50,000 cubic feet, while the three fans together supply 234,000 cubic feet per hour.

Situation Reviewed

Considering the problem generally, it appeared to the writer that the use of a trunk or blast system here was wrong in that it only produced, by a costly and bulky method, a renewal of air that could be quite well brought about by open windows and skylights with, perhaps, one or two inexpensive propeller type fans. What we aimed at was the ease and comfort of the workers, not the pumping in of an arbitrary quantity

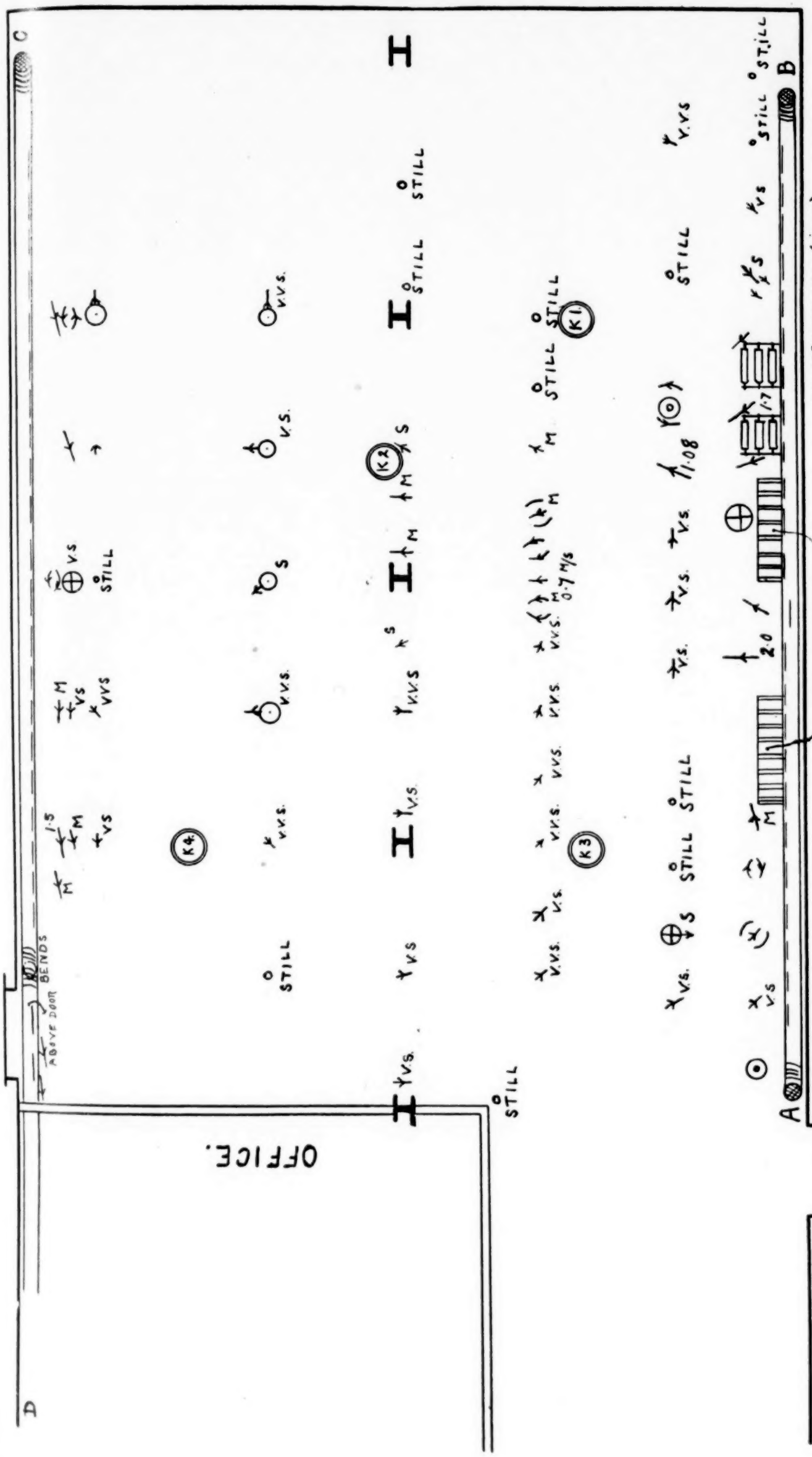

FIGURE 1

AIR MOVEMENTS CAUSED BY ACTION OF THREE 1½ HP BLOWERS AT A, B & C.

M. Moderate current
S. Slight "
V.S. Very Slight "
V.V.S. Extra Slight "

Figures indicate meters per second e.g., 1.08.

of air so that it could be said that the shops were properly ventilated; this would not increase the production of the factory nor lessen the labor turnover.

Dr. Leonard Hill's Methods and How They Were Applied

Dr. Leonard Hill's kata-thermometer is at present the best means available by which those physical conditions of the atmosphere that affect health may be measured, and for the benefit of those who are not familiar with this instrument a short account of its principles is given.

The working human body can be considered as a heat engine consuming its fuel (food) with an overall thermal efficiency of about 25 per cent.; that is to say, it has to dissipate to the surroundings about 75 per cent. of the heat energy of the food eaten and digested, in the same way that an automobile, in order to work without overheating and without being forced to stop, has to dispose of about 80 per cent. of the heat of its petrol's combustion through its radiator and exhaust pipe, and from the surfaces of its engine. The human engine's radiator is its skin, externally on the body surface and internally on the respiratory membrane, through which heat is lost by contact with air at a temperature lower than its own, and by the evaporation of moisture from the warm surfaces, which can always take place as long as the air is not saturated. These most essential interchanges of heat are thus governed by the physical condition of the air surrounding the body. The kata-thermometer has been invented by Dr. Hill to enable us to measure and compare these physical conditions as they occur in everyday life.

The kata-thermometer[1] is a large bulbed spirit thermometer, the bulb of which is heated well above body temperature for each observation. The instrument is then suspended freely in the air that is to be tested, and the time taken by the meniscus to fall from 100°F. to 95°F. is measured (the mean of these figures being taken as the temperature of the skin).

As is well known, the amount of moisture present in the air has a great influence on comfort, and if it is remembered that evaporation plays an important part in disposing of the body's waste heat, the reason for this is clear. The kata-thermometer can be used as a dry or wet bulb, and in the latter case it has been proved that the additional increased cooling rate obtained is entirely due to the evaporation of the water from the wet jacket. This evaporation loss is greatly increased by air movements.

Dr. Hill in "The Science of Ventilation and Open Air Treatment"[2] maintains that alterations in the cooling and evaporative powers of the air acting on the human body, as measurable by the kata-thermometer, have a vastly greater effect upon human comfort and fatigue than have changes in the chemical composition of the air in crowded rooms. He has pointed out that the atmosphere of a stuffy London workshop contains a greater concentration of oxygen per cubic foot than the air at a Swiss mountain health resort, and that the very different physical effects and sensations produced in these places is due to other causes than diminution of oxygen. He has recorded kata-thermometer readings in factories, schools, mines, aeroplanes, army huts, and in roads, gardens, fields, on the seashore and mountains, and has collected readings from all parts of the world. He has taken

[1]Made by J. Hicks, 8, Hatton Garden, London, E. C.

[2]Hill, L.: Science of Ventilation and Open Air Treatment. Parts I and II. Med. Research Council, Special Rep. Series, Nos. 32 and 52. London, 1919, 1920.

readings in schoolrooms ventilated and heated by plenum systems, by open windows and hot water pipes, and has found that in the "plenum" rooms monotonous conditions obtain that tend to keep the occupants from enjoying an active and vigorous state of mind. He has also shown that this cooling power depends not only upon the temperature of the air but upon its *movement* past the body that it has to cool, and that movement has a greater effect upon the cooling power than temperature has, so that working in gently moving air at 85° is far more comfortable than working in still air at 80°.

Here seems to lie a key to the problem of keeping good working conditions in a factory in hot weather. To make work in a factory in hot weather no more trying than working out of doors in the shade in hot weather, we must imitate indoors, by any means in our power, the constant small movements of air that take place out of doors in the stillest of weather. Provided the air is reasonably clean and free from dust, we shall then introduce into our factory much of the freshness that is considered inseparable from outdoor life.

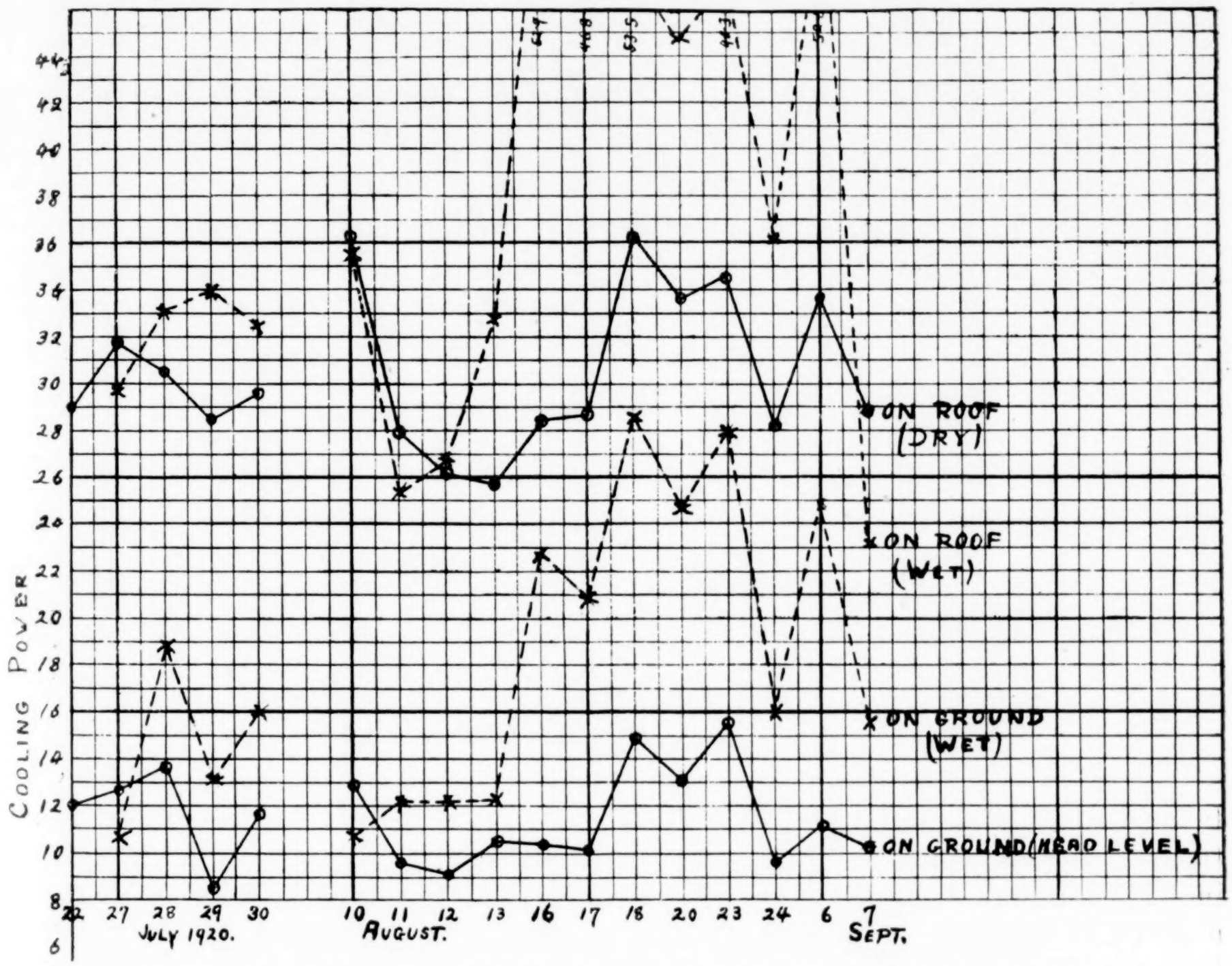

FIG. 2.—Kata-thermometer readings taken in two positions outside the factory.

Kata readings taken outside a factory on a sunny day may show a cooling power of 15, and inside the factory at the same time the kata may show a cooling power of only 5, although the inside of the building may be only 4 or 5 degrees

hotter than the outside shade temperature. This great difference is due solely to the stillness or stagnation of the air in a closed space.

The accompanying graphs show a number of kata-thermometer readings taken within the same two hours over a number of days: Figure 2 gives those taken in two positions outside the factory; Figures 3, 4 and 5 give those taken in certain positions in different departments of the factory while work was actually in progress. The upper curves are from the wet kata readings and the lower are from the dry kata readings. The great differences that occur between the outdoor readings from day to day in the fickle English climate will be noted.

The figure for opening space, which accompanies each indoor reading, is an indication of the natural ventilation available through open doors, skylights and ventilators in the department under consideration. This figure is obtained by multiplying the approximate free area in square feet of all openings by 1,000, and dividing the product by the cubic foot contents of the building, giving square feet of opening per thousand cubic feet of space in the building.

In this connection Figure 3 should be especially noted. Here the broken line

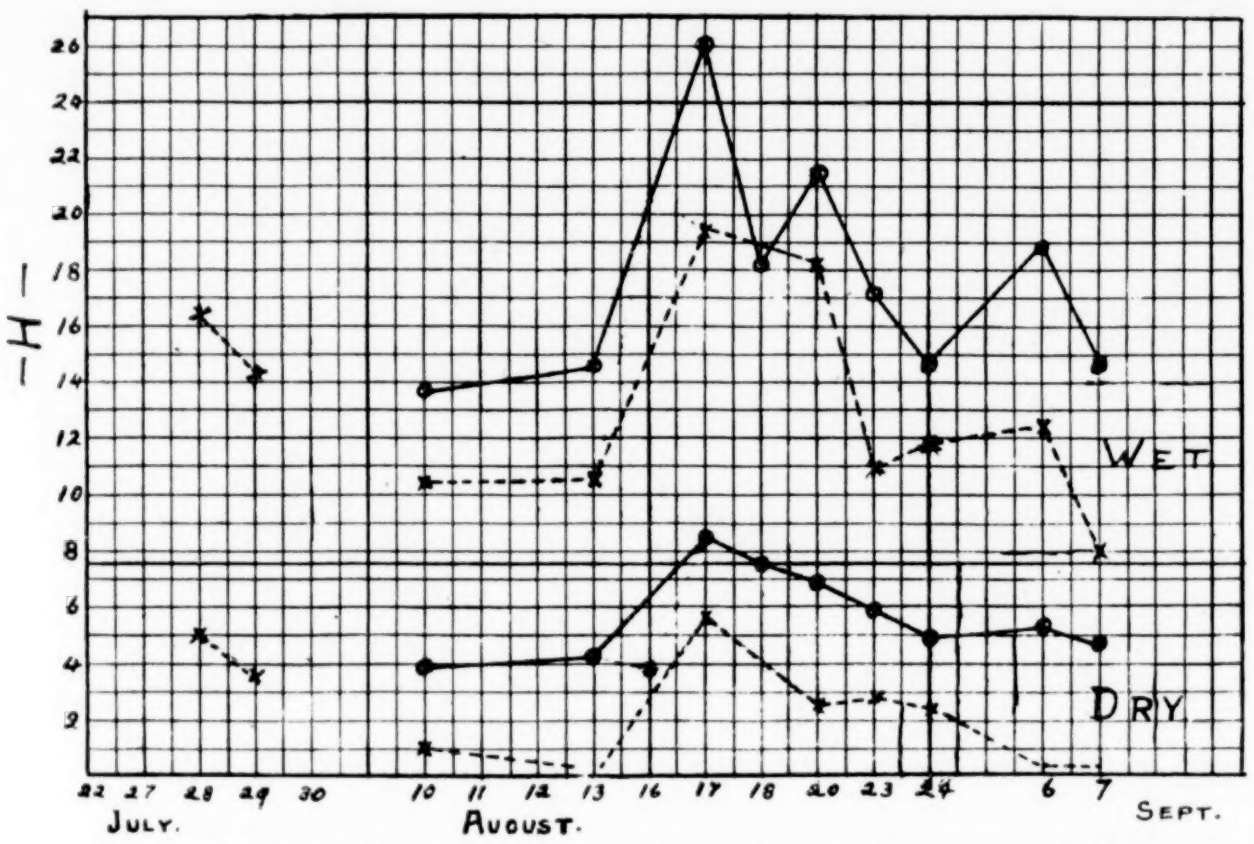

FIG. 3.—Kata-thermometer readings taken in new moulding shop and in old moulding shop.

Solid line=new moulding shop; broken line=old moulding shop.

In new moulding shop doors=7.3; roof openings=1.36; making opening figure 8.66.

In old moulding shop doors=1.62; roof openings=0.70; making opening figure 2.32.

indicates readings in the old moulding or curing shop, a place containing many steam curing pans and provided with comparatively small vents for the hot air, or side openings for cool air to enter. The opening figure is 2.32 and the lowest dry kata cooling power is 0; the temperature when this reading was taken was above 96.5°F. The solid line pertains to the new moulding shop where bountiful side windows and roof lights are provided. Here the opening figure is 8.66, and the lowest dry kata reading is 4.

In these two departments the work done and the sources of heat are identical; in the first department men be-

come bathed in sweat after a few minutes' work, and are generally exhausted by the end of the day; the other department only impresses the worker as being "rather too warm." The difference

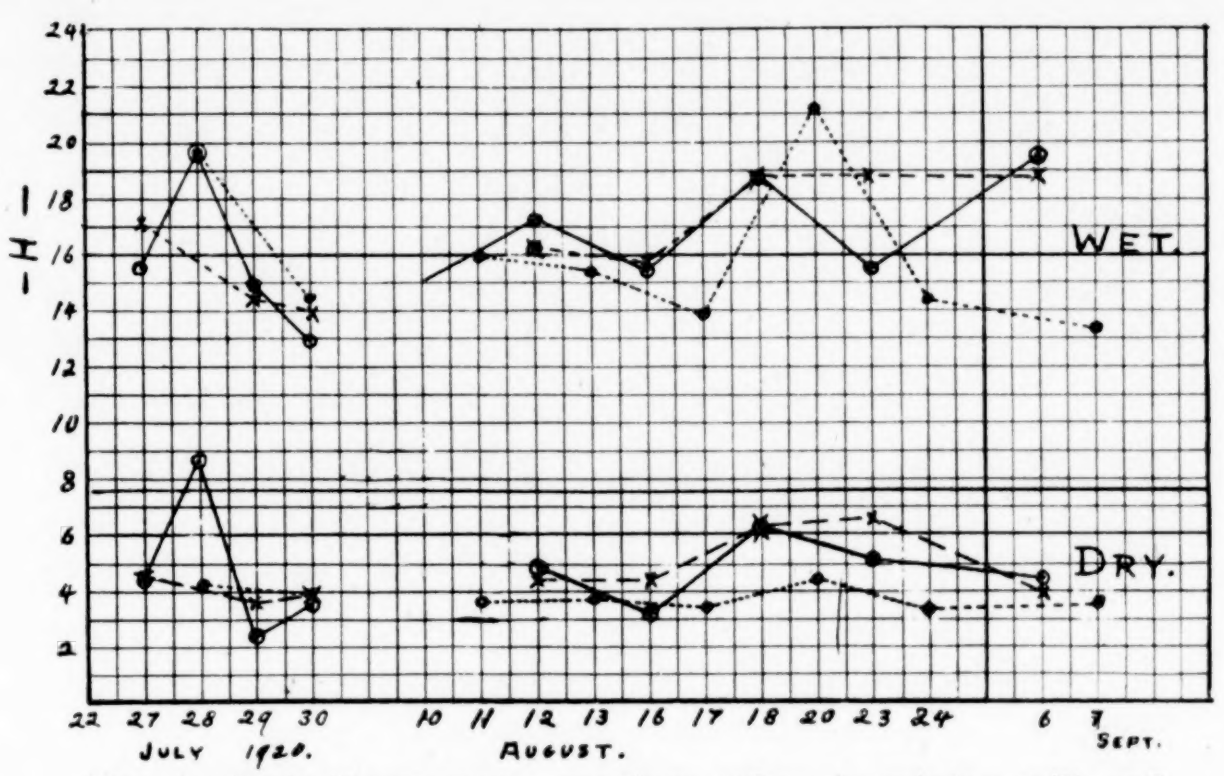

FIG. 4.—Kata-thermometer readings taken in mixing mill and in extruding shop.

Dotted line=mixing mill; solid and broken lines=extruding shop.

In mixing mill doors=1.64; no roof openings; making opening figure 1.64.

In extruding shop doors=0.85; roof openings=0.96; making opening figure 1.81.

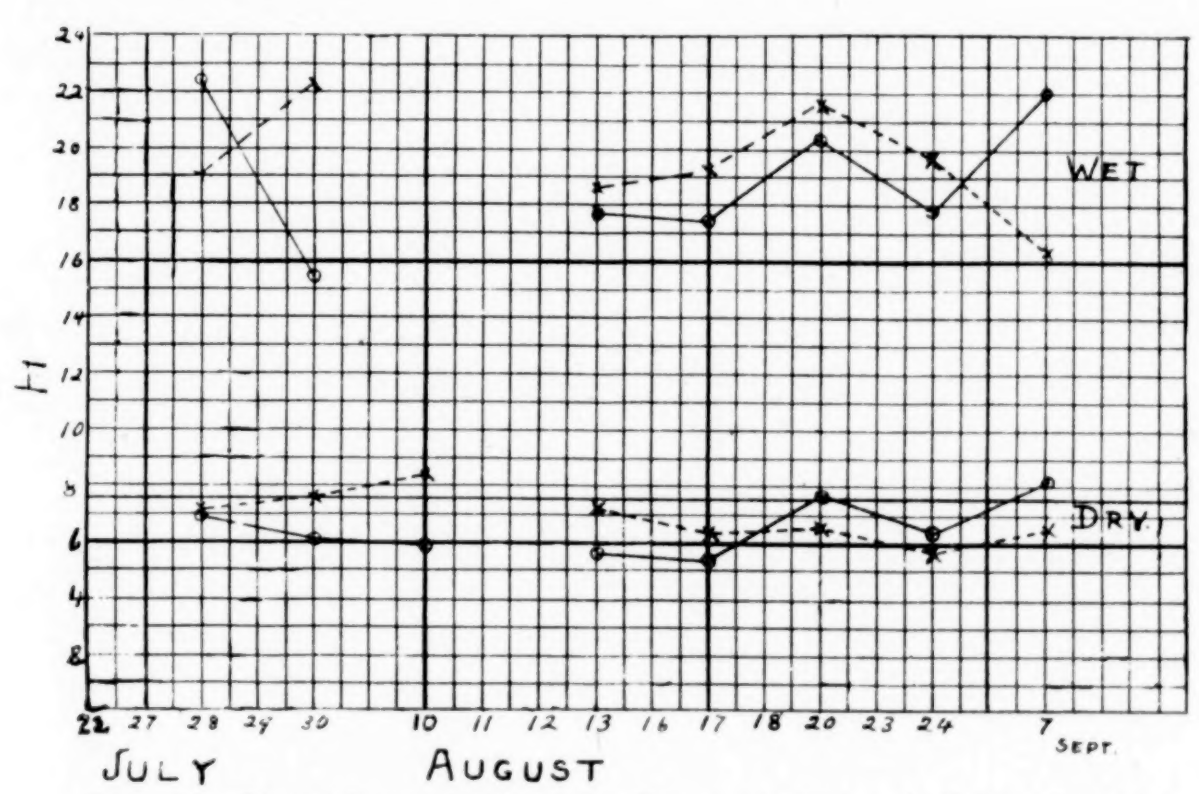

FIG. 5.—Kata-thermometer readings at two stations in test department at same hour.

Doors=1.55; roof openings=1.70; making opening figure 3.25.

is obtained by no greater effort than a careful provision of natural ventilation openings.

The departments cited are two of those where the greatest excesses of heat are found in these works, and where structural alterations were called for, in order effectively to dispose of the large quantities of heat, steam and fumes that are inseparable from the processes. We have now to consider the larger part of the factory where processes entailing no large production of heat are carried out, but where the sensations and the kata-thermometer prove

that the conditions are too enervating.

A typical series of kata readings for such a place is shown in Figure 4. These readings were taken in the mixing mill and extruding shop, where the opening figures are 1.64 and 1.81, respectively; while the average dry kata reading is about 4.5, and the wet kata 17, instead of the figures 7.5 and 24, which are considered ideal for moderate physical work. Compare these figures with those for the test department (Fig. 5) where the opening figure is 3.25, and the dry and wet katas 6.5 and 19.

It is plain that roof and wall openings, though of great use in hot weather, will, even if the construction and position of a factory permit their being made, be only a partial remedy for stuffy conditions in hot weather. At best it is only reasonable to suppose that natural ventilation can keep the inside temperature down to that of the outside air, and in practice even this is rarely attained. The ideal factory would be one with walls which could be entirely removed in summer, so that the occupants, while shaded from the sun, would be stimulated by the constant movements of the air.

In public buildings and theatres ventilation engineers are in the habit of relieving stagnation of the air by introducing conditioned air at a suitable position at one side of the room and removing it at the other; a given volume of air thus traverses a space of known volume at a known average velocity. It is hardly necessary to point out that a conditioned air supply to a factory like the one under investigation, besides being quite unnecessary, would be altogether out of the question.

In small rooms and offices air movements can be produced at will by small electric fans, and in restaurants by larger fans suspended from the ceiling. Both of these have the desired effect: they "make the place feel cooler and fresher"—that is to say, they cause the air to move faster around the bodies and faces of the people present, and this air, being cooler and dryer than the surfaces, has a pleasant cooling effect.

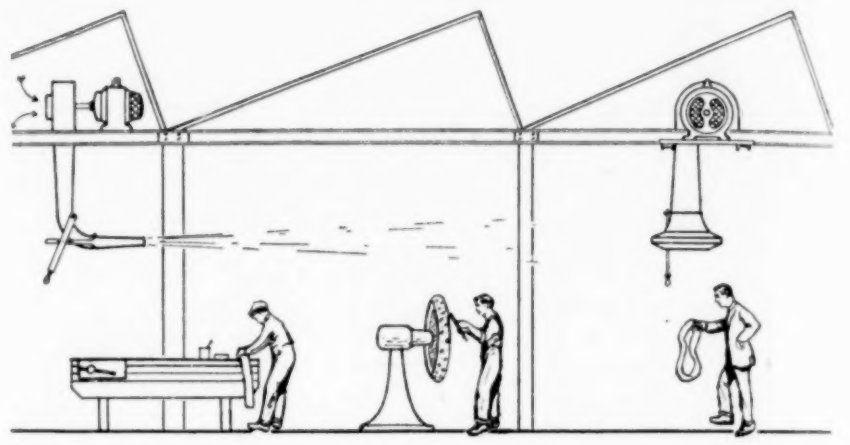

FIG. 6.—Side and front views of jet tubes as fitted up in a factory.

It appeared to the writer that none of the usual methods of promoting air movements were applicable to factory conditions, where cooling effects, to be of any real use, must be produced over very large floor spaces, and at the level of the head and shoulders rather than at the level of the feet, and must in no part of the building cause unpleasant drafts.

The Jet Tube.—In order to meet these conditions the writer introduced the jet tube system, by means of which it was hoped to cause air movements of the right kind over a large floor area. A jet tube consists of a sheet iron tube or trunk terminating in a wide, flat opening, through which air is driven with high velocity by means of a low pressure centrifugal fan. The flat, wide stream thus produced passes well over the heads of the people but its force is sufficient to set in motion a great volume of air around its path. This surrounding air gets a general drift in the direction of the jet but it is also thrown into eddies and whirls that to some extent

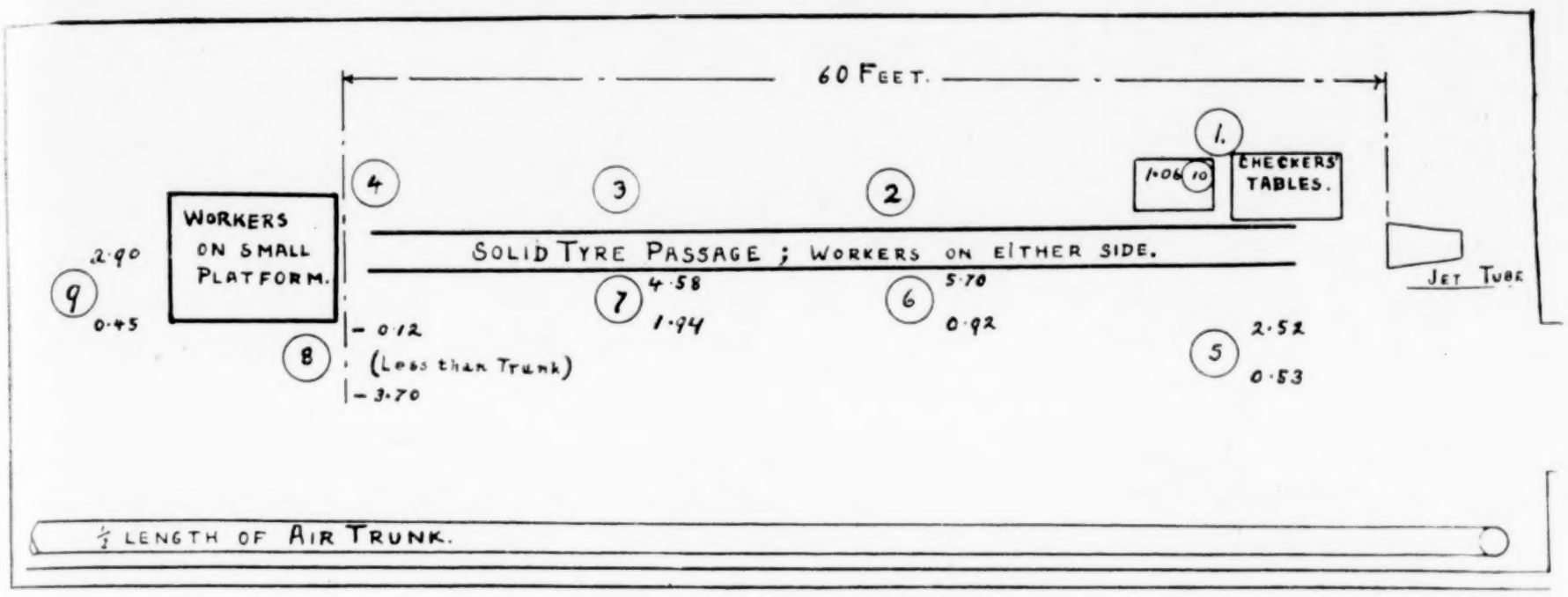

FIG. 7.—Kata-thermometer stations during air trunk and jet tube test in erecting shop. Cooling power increases due to jet tube at head and feet are marked beside stations. For example, at station 6, the increase was 5.7 at head level, and 0.92 at foot level. At station 8 the jet tube had less effect than the air trunk.

TABLE 1.—COMPARISON OF EFFECTS OF JET TUBE AND OF AIR TRUNK

Position and Fans	Temperature at Shoulder Level		Dry Kata Cooling Powers		Cooling Power Increase	
	Dry	Wet	At Head	At Feet	At Head	At Feet
	°F.	°F.				
1. All off	74.0	65.0	4.36	4.75	–0.15	0.22
Trunk on	74.0	65.0	4.21	4.97		
2. All off	74.5	64.5	4.70	5.05	–1.45	–0.08
Trunk on	74.0	64.0	3.25	4.97		
3. All off	75.0	64.0	3.98	4.44	1.13	3.83
Trunk on	74.0	63.0	5.11	8.27		
4. All off	74.0	65.0	4.40	4.50	0.10	0.72
Trunk on	73.0	64.0	4.50	5.22		
5. Trunk on	79.0	72.0	3.98	3.47	2.52	0.53
Jet tube on	79.0	70.5	*6.50*	*4.00*	(increase over trunk)	
6. All off	77.5	70.0	4.00	3.98		
Trunk on	77.0	70.0	4.37	3.92	0.37	–0.06
Jet tube on	78.5	69.0	*9.70*	*4.90*	5.70	0.92
7. All off	78.0	71.5	3.68	3.65		
Trunk on	76.0	69.0	5.31	5.74	1.63	2.09
Jet tube on	78.0	69.5	*8.26*	*5.59*	4.58	1.94
8. Trunk on	76.0	68.0	6.34	8.30	–0.12	–3.70
Jet tube on	78.5	69.5	6.22	4.60	(less than trunk)	
9. All off	78.0	71.5	3.60	3.55	0.55	0.04
Trunk on	78.5	71.5	4.15	3.59		
Jet tube on	79.0	70.5	6.50	4.00	2.90	0.45
10. All off	78.0	71.0	3.36	—	1.06	—
Jet tube on	79.0	71.0	4.42	—		

prevent the monotonous sensation produced by a steady current of air. The jet, though starting at a height well above the heads of the occupants, is generally slightly canted downwards so that as its force lessens with distance, its

effect is increased as it nears the floor.

In this way it was found that a single jet tube supplied with air by a 1½ horse power motor had a measurable effect over a floor space of roughly 100 feet by 15 feet, and that five jet tubes could keep in motion the whole air in a large building.

ing power should be about 7.5 and that without artificial ventilation the cooling power was only from 3 to 4.5 on a hot, stuffy day, it will be seen that the jet tube produced a marked cooling effect on all the workers in a space of more than 700 square feet. It will also be noted that this was invariably greater

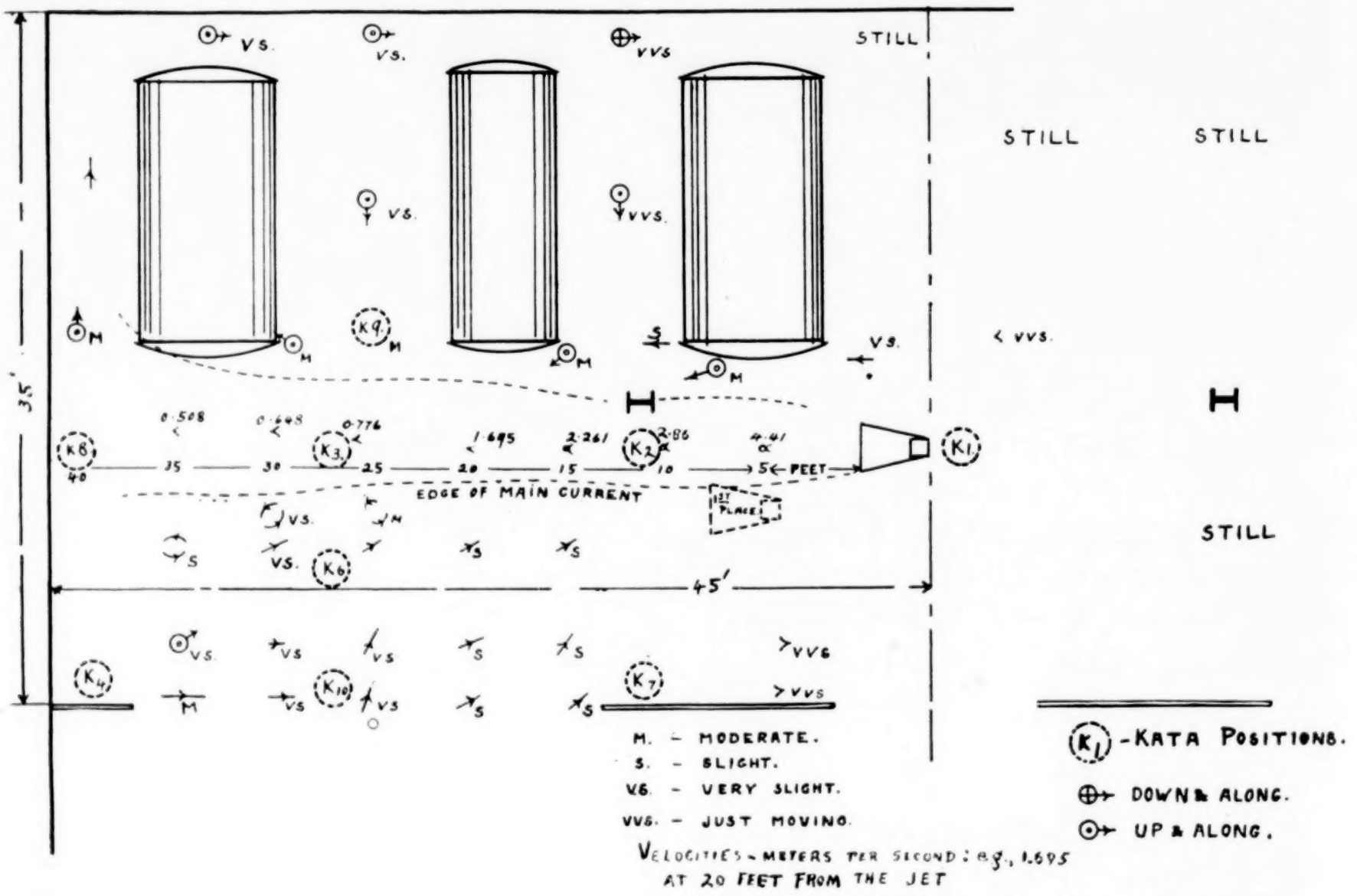

FIG. 8.—Effect of horizontal draft in curing shop from a ½ horse power blower drawing fresh air.

Figure 7 shows how one of these jet tubes was set up over the track of a manufacturing process so that it would blow over the heads of two long lines of workers, between whom the articles passed. The effect of the jet tube is compared with that of one of the air trunks already referred to, which was fixed to the wall at the side (Table 1). The jet tube and the air trunk were worked by motors of identical type and power.

Remembering that the dry kata cool-

at the head than at the feet: stuffy heads and cold feet are good for no one.

The air used in the jet tube was the warm air from inside the roof of the building untreated in any way; its temperature was 82.5°F., and that of the fresh air from the trunk was 68°F. It will be seen that the warm air cooled the workers more than did the cool air. The negligible effect on the *temperature* caused by the introduction of 1,000 cubic feet per minute of outside air 14.5° cooler than that of the building is

notable. It should also be noted that in some places the trunk produces a large and undesirable cooling power at the feet. (See positions 3 and 7.)

Figure 8 shows the effect of a jet tube working at ½ horse power only, placed in a curing shop for the benefit of the men working in front on three large steam-heated curing pans. The temperature here was generally over 80°F.; the cooling power increases at the various stations are given in Table 2. The temperature of air from the jet tube was from 40° to 50°F.

The air movements were investigated by means of smoke clouds, and their directions and comparative velocities are indicated on the plan shown in Figure 8. The jet was 8 feet above the floor, and it will be seen that it caused a marked general movement of air in the building. The effect of the jet tubes can be varied to suit prevailing conditions by controlling the speed of the fan motor and by altering the inclination of the jet to the ground.

TABLE 2.—EFFECT OF JET TUBE ON COOLING POWER IN CURING SHOP

Position		Temperature		Cooling Power (Dry)	Cooling Power Increase Due to Jet Tube
		Dry	Wet		
		°F.	°F.		
K 1	Off	75.0	66.0	3.71	1.09
	On	—	—	4.80	
K 2	Off	79.0	70.0	3.62	8.98
	On	75.0	65.0	12.60	
K 3	Off	77.5	67.0	3.95	2.35
	On	77.5	65.5	6.30	
K 4	Off	78.0	68.5	3.50	1.05
	On	76.5	67.5	4.55	
K 6	Off	—	—	3.21	0.25
	On	—	—	3.46	
K 8	Off	76.0	67.0	3.85	1.17
	On	78.0	68.0	5.02	
K 9	Off	82.0	70.0	2.24	0.26
	On	84.0	70.5	2.50	
K 10	Off	80.0	69.0	3.21	1.09
	On	81.0	69.0	4.30	

Conclusions

The following summarizes the results obtained in the eighteen months during which this research was carried out.

Maintenance of Equable Temperatures in Hot Weather.—The introduction of fresh air by centrifugal fans in quantities sufficient to keep down the temperature of a large factory appears to be difficult and costly. In all possible cases ample roof and side openings should be made, and in most cases they should be so arranged that they can be closed completely in cold weather. Side and roof openings should be of approximately equal area, and the ratio of their sizes to that of the building which they are to ventilate, should depend upon the nature of the work that is to be done in the building.

The following appear to be suitable opening figures for buildings of the class under consideration:

Building and Nature of Work	"O" = Opening Figure sq. ft. × 1000 / cu. ft. content
Offices	3.0
Laboratories	4.5
Chemical laboratories	5.0
Light manual work on cool processes	5-6
Light manual work with moderate heat	6-7
Heavy work with great heat	9-11

Many more data of opening figures in well ventilated and badly ventilated buildings are required. The actual air flow through roof and side openings, due to a known difference of inside and outside temperatures, should be determined in perfectly still weather with a view to designing these openings so that a reasonable temperature difference will never be exceeded when all are open. In this way the air changes due to natural ventilation in hot, still weather may be determined, and this would enable the sizes of suitable propeller type fans to be determined for those buildings in which, for any reason, it is impossible to provide the requisite natural ventilation openings. Thus, by observing the heat-induced air changes that take place in a number of naturally ventilated buildings it would be possible to say what fans will be required to maintain an equable temperature in buildings where natural ventilation cannot be used.

The following formula is proposed for use in determining the velocity of air into a building through side openings, and out of it through roof openings of equal area:

$$V = \sqrt{g(H - \frac{Ht}{T})}$$

Where V = velocity of air in feet per second.
H = vertical distance between centers of roof and wall openings in feet.
t = absolute temperature of outside air.
T = absolute temperature of inside air.
g = 32.2.

Cooling Power.—The cooling power of the air as measured by Hill's katathermometer has an enormous effect upon human comfort. Air movements, drafts, and eddies are great determinants of cooling power.

In cold weather drafts are unbearable; in hot weather they are a godsend, and instead of popularly being called drafts are spoken of as "fresh air," whether the air is fresh or merely the air of the enclosure in a state of movement.

In order to get the best working conditions in a factory it is necessary to give proper attention to the movement of the air around the occupants, and to vary this to suit the climatic conditions.

THE INFLUENCE OF BENZOL UPON CERTAIN ASPECTS OF METABOLISM*

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INTRODUCTION AND HISTORICAL

THAT benzol (benzene, C_6H_6) is a substance which warrants a more complete study as to its pharmacological and toxicological action is being emphasized by the increasing reports in the literature, not only of Europe, but also of America, of cases of both acute and chronic poisoning which frequently terminate fatally. In Europe, especially in Germany, benzol has long enjoyed an extensive use in the industries, particularly in the manufacture of rubber goods, in dry cleaning, and in the preparation of quickly drying paints because of its powerful solvent action and its quick evaporation. From time to time one finds reports in the literature of both acute and chronic poisoning, and its action on the blood has been noted and thoroughly discussed.

Up to 1914 benzol had practically little use in the United States. Petroleum-benzine and naphtha had been used as solvents in the rubber industry, for they were much cheaper than benzol. With the outbreak of the Great War in 1914, however, two things were brought about:

1. The supply from Germany not only of benzol but also of aniline, which had become a valued ingredient of compound rubber, was shut off.

2. A sudden demand was created for benzol and toluene for the manufacture of explosives, and for aniline for the manufacture of dyes as well as of rubber. As a result, coke by-product plants were erected to secure benzol and toluol. With the armistice there came a sudden cessation of the manufacture of explosives and, with it, a need for new markets for the enormous quantities of coal-tar distillates (benzol among them) which were thrown back on the hands of the producers. These markets have been found in the rubber industry, especially for tires, footwear and hose; in sealing mixtures for tin cans; in the shoe trade for cement; in certain processes in the making of straw hats; as a solvent for fabrikoid; and as a substitute for gasoline in motor car fuel. Benzol is therefore much cheaper now than the solvents previously used and, being also a more powerful solvent, is replacing those previously used. Indeed, it is not improbable that the coal-tar distillates will soon supplant the petroleum distillates in the making of spread rubber goods and dipped rubber goods as they have in Europe.

In America, before 1914, Selling(1) reported a few cases of chronic benzol poisoning from a can factory where rubber dissolved in benzol was used as a sealing fluid. At that time no cases of severe acute benzol poisoning were on record, but in 1915 to 1916 Alice Hamilton(2) reported fourteen cases of sudden acute poisoning with seven deaths, and since that time the danger of such an accident has become familiar to engineers, chemists, and safety experts. The danger of chronic poisoning is less well-

*The data are taken from a thesis by Dr. Benedict R. Harris presented in candidacy for the degree of Doctor of Medicine, Yale University, 1922.
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known and, inasmuch as it is becoming an increasing menace in this country, it is essential that the medical profession should better acquaint itself with the conditions under which it may be looked for, its warning symptoms, its pharmacological, pathological, and toxicological effects. It was with the intention of endeavoring to add a little more to the knowledge of its toxicity that this study of the effect of benzol upon certain aspects of metabolism was undertaken.

Acute Benzol Poisoning

In 1912, the reports of the German factory inspectors (3) contain three cases of acute benzol poisoning, two of them fatal. One man was painting the interior of a barrel with benzol tar paint; the other, a worker in a dry cleaning establishment, had climbed into the washing machine which had a little residue of benzol at the bottom. The third, who was in charge of a distilling plant, had neglected to turn on the cold water for condensation, and the fumes that escaped killed him. A similar case was reported by the British factory inspectors (4) in 1918. In America, the earliest instances of acute industrial benzol poisoning seem to have occurred in connection with the war industries in 1915 to 1916, the men being pipe-fitters or workmen engaged in distilling benzol or cleaning tanks (5). In more recent years a decided effort has been made to avoid such accidents, but if a man is susceptible, it takes only a small quantity to poison or even to kill him. Cases of extreme susceptibility to very small amounts of benzol have been reported by Lewin (6), Harrington (7), and others. Rambousek (8) described thirty-four cases, of which twenty-two proved fatal.

Symptoms (9).—In slight cases there is giddiness and a stage of excitement, which, if the vapor is inhaled in quantity, is quickly followed by coma. The skin assumes a somewhat livid appearance, and convulsions or twitchings of the muscles are noticeable.

Pathology.—According to Beinhauer (10), in acute benzol poisoning the blood in the heart and vessels is fluid, the veins of the abdomen are engorged. There are hemorrhages into the gastric mucosa, bloody foam in the air passages, no benzol odor, and no benzol demonstrable chemically. Sury-Bienz (11) found conspicuous bright red spots over the body, the blood fluid and dark, petechial hemorrhages into the gastro-intestinal mucosa and pleura, general venous congestion, and bloody mucus in the air passages. Lehmann (12) of Würzburg, experimenting with cats, found a decided variation of susceptibility in individuals but all of them showed signs of irritation of the mucous membranes, muscular twitchings, and a fall of body temperature. In large doses there were convulsions, narcosis, very deep respiration, first quick then slow, quickened pulse, and death from respiratory paralysis. In man, 15 mg. (¼ grain) per liter of air produces listlessness and confusion after half an hour, and exposure to from 20 to 30 mg. (1/3 to 1/2 grain or from two to three parts per 100,000 of air) for a few hours may cause loss of consciousness.

Chronic Benzol Poisoning

Santesson (13) in 1897 reported nine cases of chronic benzol poisoning in young women, aged 15 to 20 years, employed in a velocipede tire factory in Upsala, using benzol rubber cement. Four of them died after exposure for

three weeks to four months. Selling (1) in 1910 described similar intoxication in girls aged 14 to 16 years, employed in a Maryland can factory, in which the sealing mixture consisted of rubber and resin dissolved in commercial benzol. In 1916 McClure (14) reported a case from the same factory, and two more cases were reported in the same year, one in a boy aged 17, the other in a woman aged 57. Harrington (7) of Boston reported five cases with three deaths in an automobile tire factory. Two fatal cases were brought before the New York State Workmen's Compensation Commission (15) in 1920. These men had been engaged coating fabrikoid with a mixture consisting of nitrocellulose, pigment, castor oil, grain alcohol, benzyl, and ethyl acetate.

Symptomatology. — Briefly, chronic benzol poisoning takes the form of an aplastic anemia with subcutaneous hemorrhages and bleeding from the mucous membranes as terminal changes. Cases are all so similar that the symptoms and pathology may best be illustrated by the report in full of one of Selling's (1) cases.

Case 1.—M. W., white, female, aged 14 years. Occupation: factory hand.

The patient was first seen by Dr. Girdwood about June 1, 1909. At that time he was treating the mother for pneumonia and his attention was called to the daughter incidentally by her marked pallor and by the presence of a purpuric eruption. She was feeling perfectly well. Shortly after this she began to have haemorrhages from the mouth and nose, and she was advised by Dr. Girdwood to enter the hospital.

She was admitted to the Johns Hopkins Hospital on June 28, 1909, complaining of "spots on body and dizziness."

Family History.—One uncle died of tuberculosis.

Past History.—Negative except for mumps, chicken-pox, and two attacks of measles. She had been working in the canning factory for about four months at the coating machines. During this period she had no symptoms whatever and stopped work because of her mother's illness.

Present Illness.—The patient dates the present illness from the latter part of May, 1909, about one month before admission, when she first noticed blue spots on her arms and legs. These, she states, came out slowly and a few at a time. Shortly after this, she began to have bleeding from the gums, nose, and throat, one attack of epistaxis lasting two days. A few days before admission there was a very severe haemorrhage from the throat, controlled only with difficulty by local applications. For the past week she has been in bed, the chief symptoms being weakness and dizziness. There have been no joint pains and no gastro-intestinal symptoms.

Physical Examination on Admission.—Patient is a well-built, well-nourished girl. Skin shows a marked waxy pallor, and mucous membranes are very pale. Scattered over the arms and legs, and, to a less extent, over the trunk are purplish-red to blue macules, which are 1 to 3 mm. in diameter and which do not change on pressure. Several fading spots are present on the face. On the right shin there is a large ecchymosis and a similar, but smaller one, on the left shin. The gums show slight bleeding, especially about the root of a broken tooth. They are not spongy. In the region of the left tonsil and the right anterior pillar and extending up to the uvula is a dark brown necrotic looking mass surrounded by an inflamed border. This was the site of a severe haemorrhage which had been controlled by the application of ferrous sulphate before admission. No glandular enlargement.

Heart.—Negative except for systolic murmur over the precordium, which was considered of hemic origin. Lungs negative.

Abdomen.—Liver edge easily felt 2 cm. below costal margin in right mammillary line; edge sharp and soft. Spleen not felt; dulness not increased. No oedema of legs.

Ophthalmoscopic Examination.—Moderate grade of neuro-retinal oedema. Fundi very pale and flecked throughout by great numbers of haemorrhages, linear and round. These are especially numerous about the discs. The arteries are extremely pale. The veins are pale but relatively darker than the arteries.

For the first few days after admission the patient was listless, but, in spite of the marked anaemia, her condition seemed very good. There was a continuous, but slight oozing from the mouth and throat, with an occasional expectoration of a blood clot. A

few fresh purpuric spots appeared, some of them on the gums.

On July 3, the patient became very toxic. She was in a state of stupor from which she could not be aroused. The pulse was small and weak. Because of the seriousness of her condition, a transfusion of blood was attempted, following which the pulse became fuller and of a better quality, and the mucous membranes of a slightly better color. There was, however, no change in the blood count.

July 4. The condition was much improved. The patient was mentally clear. The pulse was slower and of better quality. The improvement continued until July 6, when she lapsed back into the previous toxic state. The respiration was rapid and labored, the pulse rapid and of poor quality. She became steadily weaker until the exitus which occurred on that day.

During her stay in the hospital the temperature ranged from 99.8° to 104.6° F., the pulse from 108 to 165 per minute. Blood culture and Widal negative.

The urine was normal on admission, but following the transfusion showed albumin and a few hyaline and granular casts. There was no evidence of hemolysis either in the change in the color of the urine or in the appearance of jaundice.

Blood on Admission.—The examination of the fresh blood showed the red cells smaller than normal, pale and with very pale centres; moderate anisocytosis, but no extremely large or small forms. No poikilocytosis. Marked leucopenia with predominance of mononuclears.

	R.B.C.	W.B.C.	Hgb.
June 28 ..	———	1,280	28% (Sahli)
July 1 ..	1,090,000	480	11%
July 3 ..	800,000	480	—
July 4 ..	640,000	600	8%

In all the fresh smears examined, platelets were practically absent. Coagulation time 4½ minutes.

Differential count of smears made July 3:
(Ehrlich's triacid stain.)

Polymorphonuclears	43%
Lymphocytes	41%
Large mononuclears	14%
Unclassified	2%

100 cells were counted. One megaloblast was seen; no normoblasts.

Contraction of the Blood Clot.—The blood, drawn from the ear and allowed to stand in a tube for 24 hours, showed some contraction of the clot and expression of the serum. The extent of contraction, however, and the amount of serum expressed were distinctly less than in the control tubes taken from normal patients.

Autopsy (abstract) by Dr. W. G. MacCallum. Anatomical diagnosis: Purpura haemorrhagica (probably toxic); haemorrhages in the skin, viscera, and serous surfaces; pallor of the organs.

Muscles a deep red color. Blood pale and watery. The heart muscle, and to a less extent, the liver, show some fatty degeneration.

Bone Marrow.—The bone marrow of the femur is fairly consistent; it is of a dull ochre yellow color with no abundance of bloody supply. It does not look like a markedly hyperplastic marrow.

Microscopic Report.—Malpighian corpuscles of the spleen show areas of hyaline necrosis. Otherwise the findings simply confirm the gross description.

Bone marrow, microscopic examination by Dr. Boggs. Smear from the femur marrow (Romanowski stain) shows very few cells of any kind. The predominant cell is the normal red, which is pallid and slightly basophilic and shows no great irregularity. Leucocytes are extremely scanty. They are mostly of the lymphocytic or myeloblastic type. They are characterised generally by a very definitely reduced chromatin in the nuclei. Many nuclei show vacuolization and the cytoplasm is thin, fragile and poorly stained. One megalocaryocyte seen on fairly careful examination of the cover slip. Suggests an aplastic bone marrow.

The most remarkable feature was the blood condition and this can be described as an aplastic anemia. In common with the aplastic anemia were:

1. Presence of only slight changes in the appearance of the red blood cells (slight pallor and slight anisocytosis).
2. Absence or comparative fewness of regenerative forms.
3. Scantiness of platelets.
4. Diminution of the granular types of white blood cells with a relative increase in the mononuclear element.
5. Marked leukopenia.

Santesson (13), experimentally in rabbits, by subcutaneous injection and by wrapping the bodies of the animals in cloths soaked with benzol, produced chronic poisoning and pathological find-

ings similar to those reported in the foregoing case.

Later researches of Selling (1) and those of Duke (16) show that there is:

1. A direct destruction of leukocytes with reduced formation of new elements.

2. A destructive action on blood platelets and on the megakaryocytes of the marrow from which platelets are formed.

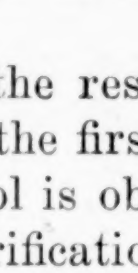
3. Destruction of adult red corpuscles and the prevention of the formation of new ones.

These changes occur in the order given, the effect on the red corpuscles being especially characteristic of very slow poisoning, the last to appear, and the last to disappear with recovery.

Hektoen (17), Rusk (18), and Weiskotten and his colleagues (19) have done much further work, showing a decrease of antibody, hemolysin and precipitin production and exact blood changes. Practically all the work thus far has been done with particular emphasis on the blood system or on the pathological findings. Aside from the work of Sohn (20) in 1913, in which the excretion in the urine of neutral sulphur, urea nitrogen and ammonia nitrogen was studied, the influence of benzol upon metabolism has not been given much attention. It was with the idea of studying the metabolic effects more thoroughly that the present investigation was undertaken.

Chemical Composition of Benzol

Before taking up the experimental work a few words as to the chemical nature of benzol will not be out of place. Three substances are to be considered—benzene, benzol, and benzine. Benzene is a definite chemical substance with the formula C_6H_6.



The term benzol is used in two senses, first as a synonym for benzene, and, second, to designate a variable mixture derived from the distillation of coal tar. The fractional distillation of coal tar yields primarily four products.

1. Crude naphtha distilling below 180°C.

2. Dead oils or creosote oils distilling from 180° to 270°C.

3. Green or anthracene oil distilling above 270°C.

4. Pitch, the residue.

It is from the first fraction that commercial benzol is obtained by redistillation and purification. The benzols of the market vary widely in composition according to the source from which they are derived and the extent of purification. In general, they consist chiefly of benzene and its homologues (toluene, $C_6H_5CH_3$, and xylene, $C_6H_4(CH_3)_2$) and small percentages of other substances. *Benzine,* with which these two substances have been confused, is a derivative, not of coal tar, but of petroleum, consisting chiefly of hexane, C_6H_{14}, and heptane, C_7H_{16}. Usually it contains no benzene, C_6H_6.

Practically all that is known of the pharmacology of benzol is that it is partly oxidized in the body to phenol (15 to 30 per cent.) catechol and quinol, and excreted as phenol sulphates. A part is changed to muconic acid, and a considerable portion is excreted unchanged by the lungs.

Experimental

Methods.—The experiment was divid-

ed into three main parts, in which the following were investigated:

A. The influence of starvation upon urinary composition.

B. The influence of benzol upon urinary composition.

C. The influence of benzol upon blood elements.

(Parts B and C were concerned with benzol administered subcutaneously.)

Healthy male rabbits which had previously been well fed on a mixed diet were used in this investigation. Urinary excretion was divided into twenty-four hour periods for five days by emptying the bladder by pressure upon the abdominal wall. Three rabbits were used in the investigation of the influence of starvation upon urinary composition and eight rabbits, which had previously been starved for twenty-four hours, were used in the investigation of the influence of benzol upon urinary composition and upon blood elements. Water was given, *ad libitum*. The benzol was administered subcutaneously in the groin, mixed with equal parts of cottonseed oil, aseptic precautions being taken. The dosage was 2 c.c. of benzol per kilogram of body-weight. At twenty-four hour intervals blood was drawn from an ear vein and counts made of the number of red and white blood corpuscles. All blood counts were made with a Leitz Hemocytometer, with Neubauer ruling, certified by the American Bureau of Standards.

The following urinary constituents were determined:

1. Total nitrogen.
2. Creatinine (preformed).
3. Creatine.
4. Phosphates.

In addition, the following were also noted:

a. Weight.
b. Fluid intake.
c. Urine output.
d. Specific gravity.
e. Reaction to litmus.
f. Presence of albumin.
g. Reduction of Benedict's solution.
h. Titratable acidity.

All the determinations were made according to the methods as set forth in Underhill's "Manual of Selected Biochemical Methods."

1. Total nitrogen—Kjeldahl method.
2. Preformed creatinine — Folin's colorimetric method.
3. Creatine—Folin-Benedict method.
4. Phosphates—Titration with uranium acetate.

The Influence of Starvation upon Urinary Composition

Typical analytical data are summarized in Table 1.[1] It can be seen from these data that under ordinary starving conditions, only water being given, the following changes in urinary composition are effected:

1. There is a gradual but progressive increase in the amount of total nitrogen excreted.
2. Creatine, which is present in but very small quantities at the beginning of starvation, rapidly increases in amount as starvation progresses.
3. The elimination of creatinine remains fairly constant, decreasing slightly as inanition progresses.
4. There is at first an increased elimination of phosphates followed after the second day by a progressive decrease.

The Influence of Benzol upon Urinary Composition

The following results were obtained:

[1] Illustrative data only are given both here and later. Additional experiments confirm these figures throughout.

1. There was a gradual decrease in weight.

2. The water intake varied, being usually high in the first day of starvation and then gradually diminishing.

TABLE 1.—THE INFLUENCE OF STARVATION UPON URINARY COMPOSITION

Rabbit H: Weight 2.0 kilos.

Day	Fluid		Urine			
	Intake	Output	P_2O_5	Creatinine	Creatine	Total N
	c.c.	*c.c.*	*mg.*	*mg.*	*mg.*	*mg.*
1	400	500	275	89	15	270
2	600	575	315	86	18	690
3	530	515	340	83	26	727
4	520	430	237	64	27	826
5	280	210	262	63	40	795
6	290	155	225	41	45	855

3. The output varied considerably with different rabbits, following no fixed rule.

4. The specific gravity varied inversely with the amount of water intake.

5. In all instances the urine was acid to litmus.

6. The presence of albumin varied; in some rabbits it was absent, and in others it was present in varying degree.

7. In no case was there a positive reduction of Benedict's solution.

8. The titratable acidity showed but little variation, being quite acid in all cases.

9. The elimination of phosphates varied. In rabbit C there was a progressive increase until death. In all the other cases there was a steady decrease either with or without a primary increase.

10. Creatine elimination increased very markedly within forty-eight hours after the injection of the benzol, being followed by a sharp fall and then a beginning increase again. In rabbit C there was a marked progressive elimination of creatinine, reaching 276 mg. before death on the fourth day of the experiment.

TABLE 2.—THE INFLUENCE OF BENZOL UPON URINARY COMPOSITION AND BLOOD ELEMENTS

Rabbit C: Adult male; weight 1.9 kilos.

Day	Fluid		Urine									Blood	
	Intake	Output	Specific Gravity	Reaction	Albumin	Reduction	Titratable Acidity	P_2O_5	Creatine	Creatinine	Total N	Red Blood Count	White Blood Count
	c.c.	*c.c.*					*c.c.*	*mg.*	*mg.*	*mg.*	*gm.*		
1	170	136	1.019	acid	trace	0	34.4	333	47	119	1.884	5,232,000	3,900
2[1]	150	195	1.020	acid	trace	0	29.6	382	88	187	3.000	5,000,000	4,600
3	160	220	1.019	acid	trace	0	32.5	429	66	220	2.745	6,400,000	4,700
4	145	145	1.020	acid	trace	0	2.5	630	48	276	2.520	6,000,000	2,400

[1] 3.8 c.c. benzol in cottonseed oil injected subcutaneously.

11. Preformed creatinine showed but little change except as noted in the foregoing.

12. Total nitrogen elimination followed fairly closely the elimination of creatine but did not increase to so great an extent.

The analytical data are summarized in Tables 2 to 5.

The Action of Benzol upon Blood Elements

In all cases the end results were the same, that is, all rabbits showed a leukopenia of varying degree. The red blood cell count showed but little variation. In all but one rabbit (that is, in seven) there was at first an increase in the number of white blood corpuscles which was very transitory, however, and was followed by a rapidly progressive leukopenia.

General Discussion

That benzol has a deleterious effect on metabolism is readily apparent from the sharp rise in the elimination of both creatine and total nitrogen following its injection subcutaneously into the animals used in this investigation, as contrasted with the slow gradual rise seen

TABLE 3.—THE INFLUENCE OF BENZOL UPON URINARY COMPOSITION AND BLOOD ELEMENTS

Rabbit D: Adult male; weight 2.5 kilos.

Day	Fluid		Urine									Blood	
	Intake	Output	Specific Gravity	Reaction	Albumin	Reduction	Titratable Acidity	P_2O_5	Creatine	Creatinine	Total N	Red Blood Count	White Blood Count
	c.c.	*c.c.*					*c.c.*	*mg.*	*mg.*	*mg.*	*gm.*		
1	275	220	1.010	acid	0	0	43.2	450	40	85	0.985	4,960,000	6,800
2	200	200	1.011	acid	0	0	44.0	520	33	108	1.140	5,520,000	6,300
3[1]	200	200	1.015	acid	0	0	49.6	480	79	116	1.440	5,630,000	12,500
4	140	116	1.017	acid	0	0	40.0	340	84	137	1.660	5,340,000	6,500
5	125	125	1.020	acid	0	0	42.4	334	82	112	1.404	4,896,000	4,600
6	115	100	1.026	acid	0	0	36.8	320	21	108	0.879	4,768,000	3,100

[1]5.0 c.c. benzol in cottonseed oil injected subcutaneously after two days' starvation.

TABLE 4.—THE INFLUENCE OF BENZOL UPON URINARY COMPOSITION AND BLOOD ELEMENTS

Rabbit E: Adult male; weight 2.16 kilos.

Day	Fluid		Urine									Blood	
	Intake	Output	Specific Gravity	Reaction	Albumin	Reduction	Titratable Acidity	P_2O_5	Creatine	Creatinine	Total N	Red Blood Count	White Blood Count
	c.c.	*c.c.*					*c.c.*	*mg.*	*mg.*	*mg.*	*gm.*		
1	300	150	1.015	acid	0	0	36.8	260	20	103	1.072	5,800,000	6,000
2	300	260	1.012	acid	0	0	47.1	234	47	105	1.994	5,560,000	8,400
3[1]	270	230	1.014	acid	0	0	46.8	279	107	103	1.836	5,620,000	5,500
4	260	200	1.018	acid	0	0	40.0	342	157	108	1.296	5,642,000	5,800
5	225	225	1.015	acid	0	0	45.8	342	19	107	1.188	5,480,000	4,900
6	140	110	1.018	acid	0	0	28.8	234	36	104	0.884	5,540,000	4,000

[1]4.3 c.c. benzol in cottonseed oil injected subcutaneously after two days' starvation.

under conditions of ordinary inanition. The interpretation of this rise, especially of creatine, leads one immediately into a controversy which at present is far from being settled. Almost innumerable investigations with respect to creatine have been undertaken, mostly in the last two decades, and the interpretations of results obtained vary.

TABLE 5.—THE INFLUENCE OF BENZOL UPON URINARY COMPOSITION AND BLOOD ELEMENTS

Rabbit F: Adult male; weight 2.2 kilos.

Day	Fluid		Urine									Blood	
	Intake	Output	Specific Gravity	Reaction	Albumin	Reduction	Titratable Acidity	P_2O_5	Creatine	Creatinine	Total N	Red Blood Count	White Blood Count
	c.c.	*c.c.*					*c.c.*	*mg.*	*mg.*	*mg.*	*gm.*		
1	260	180	1.010	acid	0	0	10.4	160	8	106	0.884	5,860,000	5,900
2	300	200	1.015	acid	0	0	18.4	220	26	71	0.860	6,000,000	7,900
3[1]	120	100	1.010	acid	0	0	10.4	146	61	67	1.204	5,946,000	5,300
4	140	100	1.018	acid	0	0	2.4	180	174	69	1.296	5,647,000	4,300
5	90	46	1.026	acid	0	0	10.4	140	30	81	0.784	5,842,000	3,100
6	100	46	1.022	acid	0	0	10.8	120	26	85	0.760	5,872,000	2,400

[1]4.4 c.c. benzol in cottonseed oil injected subcutaneously after two days' starvation.

Briefly reviewing some of the more recent and important work of creatine the following theories and explanations are offered. Underhill and co-workers (21) in 1916 carried out a series of experiments in rabbits and, as a result, concluded that "there is a definite interrelationship between acidosis and creatine elimination. Creatine in the urine may prove to be an index of a condition of acidosis in the organism." Later they state that "creatinuria may occur in states of acidosis when carbohydrate deficiency is not involved and creatine may also be present in carbohydrate deficiency even in the absence of acidosis." Mendel and Rose (22) in 1911, in a series of experiments on rabbits, conclude that: "An increase in the output of creatine is always accompanied by an increase in total nitrogen elimination. This parallelism is ascribed to a common source, namely, *true tissue* or *endogenous metabolism;*" and that "an increased formation of creatine occurs when the tissue catabolic processes are accelerated." In all events, practically all other investigators are agreed that creatine is an index of endogenous metabolism.

Conclusions

Benzol acts not only on the blood elements but exerts a catabolic influence on body tissues as a whole, as manifested by a sharp rise in creatine and total nitrogen, within a very short period after its subcutaneous injections into rabbits, far in excess of that found in rabbits under similar conditions under ordinary starvation.

BIBLIOGRAPHY

* 1. Selling, L.: A Preliminary Report of Some Cases of Purpura Haemorrhagica Due to Benzol Poisoning. Bull. Johns Hopkins Hosp., 1910, *21*, 33.
Selling, L.: Benzol als Leukotoxin. Studien über die Degeneration und Regeneration des Blutes und der hämatopoetischen Organe. Beitr. z. path. Anat. u. z. allg. Path., 1911, *51*, 576.

2. Hamilton, A.: The Growing Menace of Benzene (Benzol) Poisoning in American Industry. Jour. Am. Med. Assn., 1922, *78*, 627.

3. German Factory Inspectors Reports, 1912.

4. Benzol Poisoning. Ann. Rep. Chief Inspect. Factories and Workshops for the Year 1918, p. 78.

5. Hamilton, A.: Industrial Poisons Encountered in the Manufacture of Explosives. Jour. Am. Med. Assn., 1917, *68*, 1445.

6. Lewin, L.: Die akute tödliche Vergiftung durch Benzoldampf. München. med. Wchnschr., 1907, *54*, 2377.

7. Harrington, T. F.: Industrial Benzol Poisoning in Massachusetts. Boston Med. and Surg. Jour., 1917, *177*, 203.

8. Rambousek, J.: Industrial Poisoning from Fumes, Gases and Poisons of Manufacturing Processes. Translated by T. M. Legge. London, Edward Arnold, 1913, p. 102.

9. Poisoning by Benzene, Toluenes, and their Homologues. Nelson's Loose Leaf Medicine, *2*, p. 517.

10. Beinhauer, F.: Ueber Benzolvergiftung, sowie über die Betheiligung der Medicinalbeamten bei Begutachtung von Neuanlagen und Veränderungen gewerblicher Anlagen. München. med. Wchnschr., 1896, *43*, 915.

11. Sury-Bienz: Tödtliche Benzoldampfvergiftung. Vrtljhrschr. f. gerichtl. Med., 1888, *49*, 138.

12. Lehmann, K. B.: Kurzes Lehrbuch der Arbeits- und Gewerbehygiene. Leipzig, 1919, p. 249.

13. Santesson, C. G.: Ueber chronische Vergiftungen mit Steinkohlentheerbenzin; vier Todesfälle. Arch. f. Hyg., 1897, *31*, 336.

14. McClure, R. D.: Pernicious Anemia Treated by Splenectomy and Systematic, Often-Repeated Transfusion of Blood. Transfusion in Benzol Poisoning. Jour. Am. Med. Assn., 1916, *67*, 793.

15. New York State Workmen's Compensation Commission, 1920.

16. Duke, W. W.: Causes of Variation in the Platelet Count; Experimental Results Showing the Effect of Diphtheria Toxin, Benzol and Tuberculin on the Platelet Count in Rabbits. Arch. Int. Med., 1913, *11*, 100.

17. Hektoen, L.: The Effect of Benzene on the Production of Antibodies. Jour. Infect. Dis., 1916, *19*, 69.

18. Rusk, G. Y.: Univ. California Pub. in Pathology, 1914, *2*, p. 139.

19. Weiskotten, H. G., Gibbs, C. B. F., Boggs, E. O., and Templeton, E. R.: The Action of Benzol. VI. Benzol Vapor Leucopenia (Rabbit). Jour. Med. Res., 1920, *41*, 425.

20. Sohn, I.: Ueber die Beeinflussung des Stoffwechsels durch Benzol sammt Bemerkungen über seine Darreichung bei der Leukämie. Wien. klin. Wchnschr., 1913, *26*, 573.

21. Underhill, F. P.: Studies in Creatine Metabolism. I. Possible Interrelations between Acidosis and Creatine Elimination. Jour. Biol. Chem., 1916, *27*, 127. II. The Influence of Alkali upon Creatine Elimination during Inanition. *Ibid.*, p. 141.
Underhill, F. P., and Baumann, E. J.: Studies in Creatine Metabolism. III. The Influence of Alkali upon the Creatinuria of Phlorizin Glycosuria. *Ibid.*, p. 147. IV. The Relationship of Creatinuria to Carbohydrate Metabolism and Acidosis. *Ibid.*, p. 151.

22. Mendel, L. B., and Rose, W. C.: Experimental Studies on Creatine and Creatinine. II. Inanition and the Creatine Content of Muscle. Jour. Biol. Chem., 1911-1912, *10*, 255.

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THE THERAPEUTIC USE AND TOXICITY OF PICRIC ACID: WITH A REPORT OF TWO TOXIC CASES*

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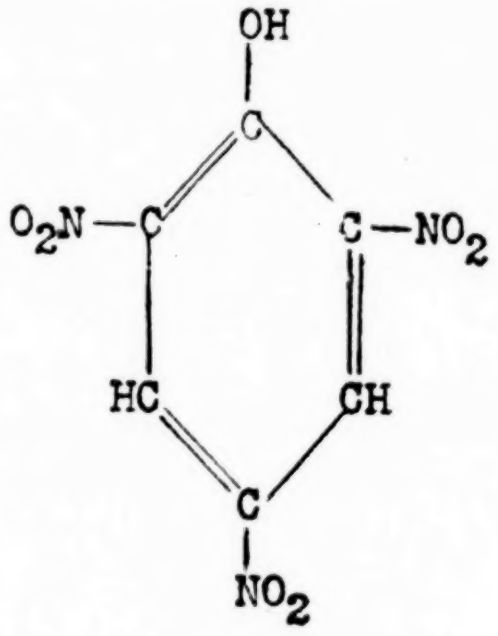
AT the present time, picric acid is one of the most common therapeutic agents for the local treatment of small superficial burns. Despite its almost universal usage, it has enjoyed the reputation of being comparatively nontoxic. Its chemical structure and the nature of its pharmacological action obviously offer possibilities of its detrimental behavior under certain conditions, as illustrated by the two cases reported herein.

PROPERTIES AND THERAPY

Picric acid is a yellow, bitter, odorless, crystalline solid. It is very easily formed from phenol, being the most important nitrophenol derivative. Officially it is known as trinitrophenol; the chemical synonyms are nitrophenic and carbazotic acid. As the structural formula indicates it is a tetra-substitution product of benzene (1).

Trinitrophenol



One gram of trinitrophenol dissolves in 78 mils of water, 12 mils of alcohol, 35 mils of chloroform, and 65 mils of ether (2). Hence the commonly employed saturated aqueous solution is of 1.2 per cent. strength, while with alcohol as the solvent, its concentration is increased about 6½ times. The saturated aqueous solution (empirically known as trinophenon) is acid to litmus, the acidity of the phenols being increased by the introduction of the nitro groups.

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The use of picric acid internally in the treatment of trichinosis and malaria is devoid of any merit. Braconnet in 1830 was responsible for its introduction for the treatment of intermittent fever. Although possessing vermicidal capabilities against tapeworm and roundworm, yet its toxic properties, when given *per os,* contraindicate its use for this purpose (3). The average dose is 0.03 gm. (½ grain). The practical value of picric acid therapy in medicine lies wholly within its sphere as a local agent.

Although used to the greatest extent for burns and scalds of the first and second degrees, it has been advised for a number of skin affections. Wilcox (4) recommends it very highly in the treatment of various skin diseases, especially acute eczema, intertrigo and herpes labialis. By some it is used as a dressing for superficial wounds, likewise for ulcers with free discharge, because of its astringent and antiseptic action. In local hyperidrosis of the feet it is a standard remedy in the form of a 2 per cent. dusting powder.

Chéron in 1876 first suggested the surgical application of picric acid, his contentions being corroborated by Curie and Vigier in 1877. For surgical purposes the saturated aqueous solution is preferable. In diseases of the skin, gauze moistened with the solution may be applied, or the solution may be painted directly over the lesion. A hydroalcoholic menstrum should be employed only in certain selected cases where the epidermis is unbroken. In superficial burns of the hands or feet the extremity may be completely immersed in the solution for two to three minutes, and then the gauze dressing placed in apposition with the affected area. This latter measure is employed by quite a number of industrial concerns, some of which place buckets of trinophenon throughout the works, so that the employees' first emergency measure, in case of a superficial burn of the extremities, is to resort to the picric acid tank. If blisters occur, they should be punctured, the serum expressed, and then the picric acid solution applied; the superficial epidermis should not, however, be removed. Hare (5) recommends the utilization of comparatively small sections of the moistened lint or gauze, since it is more easily removed in this form than in one large piece. In moderate burns the dressing is allowed to remain in place until healing is complete. In burns of the second degree the original dressing may be removed after three or four days, and the wound will often be found to be healed into a clean, soft scab. If the gauze adheres to the scab it should be moistened with the picric acid solution. When unhealed portions still remain, the gauze dressing, moistened with trinophenon, should be renewed. As a matter of fact, most of these cases are ambulatory patients, who continue working; because of the nature of their work, the dressing becomes grossly soiled, and as a rule it is advisable to renew it every twenty-four hours, rather than to leave it in place until healing is complete.

Ehrenfried (6) very concisely and accurately describes the local action of the picric acid as follows:

> Over any clean denuded surface it forms a protective, aseptic scab, by coagulation of the secreted serum, which seals up ruptured lymph-spaces, protects exposed nerve-endings, and splints the wound in such a fashion that epithelial proliferation may proceed rapidly beneath, simulating Nature's method. This artificial scab protects against infection from external sources and promotes rapid and painless epidermatization.

At first the solution may cause some pain, which is slight and of the smarting character. More often, however, it

is absolutely painless, but in all cases it speedily becomes anesthetic by virtue of its protective properties explained in the foregoing. The burned area rapidly becomes coated with the thin, very light yellow pellicle of coagulated protein.

The phenol coefficient of picric acid is 6 (Tidy (7)), so that 0.165 per cent. picric acid is equivalent in antiseptic strength to 1 per cent. phenol. Chemically this could be foretold, since it is a recognized fact that the introduction of the nitro group into the phenols increases their antiseptic action (8). According to Ehrenfried, a saturated aqueous solution destroys the Bacillus pyocyaneus in less than one minute, and Staphylococcus pyogenes aureus in two minutes, while in the experiments of Schamberg and Kolmer (9) it showed itself four times as active as phenol. Hence the utilization of picric acid as an antiseptic in burns is rational therapy.

The Toxicity of Trinitrophenol

Rapp and Föhr (1827) first investigated its toxic action on dogs. More recently Koizumi (10) has described its poisonous action on dogs and rabbits. In Ehrenfried's review of the literature, he notes that there never has been reported a fatal case of picric acid poisoning.

Taken internally it is absorbed probably as the sodium salt. The picric acid is reduced in part to picramic acid ($C_6H_2(NO_2)_2NH_2OH$) by the liver and other portions of the body. This is simply another of the many detoxicating properties of the liver. It is eliminated chiefly through the urine to which it imparts an intense yellow color, although later the urine may be colored a peculiar red (Walko, 1901) or reddish brown. After a single dose of 1 gm., the excretion of picric acid may continue for a week (11).

Trinitrophenol and its salts have a tendency to decompose the elements of the blood and to produce methemoglobin. With toxic doses it causes in the lower animals a destruction of the red blood corpuscles, but this phenomenon is rare in man; Adler in 1880 reported one instance of toxic anemia. A leukocytosis may or may not be concomitant.

The affinity of picric acid for albumin is accentuated in an acid medium, consequently it readily unites with acid tissues. This phenomenon explains the selective localization of necrotic foci in trinitrophenol poisoning. The reduction of picric acid to picramic acid is a detoxicating one, inasmuch as picramic acid does not so readily form the protein salt (12). After large doses the skin and mucous membranes, including the conjunctiva, are stained more or less yellow—the so-called "picric" jaundice; this icteric tint is actually due to the staining of the epithelium by the acid. Chéron reports an instance where the application of 0.45 gm. (6.9 grains) to the vagina produced yellowness of the skin in an hour; the patient also suffered from symptoms referable to the nervous and digestive systems (13).

The physiological dose is ½ grain, while doses from 15 to 30 grains are decidedly toxic (Lewin, Adler). The symptoms of poisoning are referred to either the gastro-intestinal, nervous, circulatory, or urinary system, or more commonly to several of these locations. Depending on the degree of the toxicity the gastro-intestinal symptoms vary from a mild anorexia, dyspepsia and flatulence to a severe diarrhea accompanied by gastrodynia, abdominal cramps and emesis, the vomited matter being stained yellow. The irritant action of picric acid on the mucous membranes is re-

sponsible for the gastritis found. The nervous manifestations vary from a slight headache and vertigo to stupor, with convulsions, followed by collapse in the extremely severe cases. Picric acid is a respiratory and cardiac depressant, but symptoms referable to these systems are rare. Adler notes, however, a primary tachycardia with a subsequent slowing of the pulse rate. Occasional symptoms are strangury and anuria. Asthenia and fever may accompany the foregoing constitutional manifestations of internal picric acid poisoning.

As stated previously, the yellow pigmentation may ensue upon internal administration, but superimposed upon this may be an erythema or even a generalized eruption of eczematous character and itching in nature. Sollmann calls attention to the fact that the dermatitis may simulate a measle rash (14).

In chemical and dye works picric acid may be classified under the industrial poisons, since inhalation of the dust causes an irritability of the respiratory tract, coryza, sneezing and inflammation of the buccal mucous membrane (Spruit). Among workers engaged in the manufacture of high explosives, picric acid may be the etiological factor in many cases of occupational dermatoses. The appearance, symptomatology and course of this dermatitis sometimes bear a marked resemblance to ivy poisoning, both of these affections being classified dermatologically as venenatous. This ensuing dermatitis is often quite severe and is extremely resistant to treatment, being accompanied at times by some of the constitutional symptoms already enumerated. At this point it should be remembered that after local application of trinophenon over extensive burned areas sufficient quantities may be absorbed to produce constitutional effects.

A Report of Two Toxic Cases

Ehrenfried treated 300 cases of small superficial burns without any symptoms of absorption. In over 100 cases of industrial burns similarly treated by the writer, there were no toxic developments, except in the two cases cited here. In all but these two instances the saturated aqueous solution of picric acid was the medicament employed. These patients were the first to be treated with a newly replenished supply of picric acid solution. The saturated aqueous solution was the strength ordered but, as subsequent investigations disclosed, the drug supplied by the pharmaceutical concern was a saturated solution of picric acid in a 10 per cent. alcoholic menstrum. As stated previously, the solvent power of alcohol for picric acid is 6½ times as strong as that of water, hence this solution (10 per cent. alcohol) contains proportionately over 1½ times as much solute as the trinophenon (saturated aqueous solution). A further deleterious effect of this preparation is that the alcohol facilitates the absorption of the picric acid.

Case 1.—A. J. G., a plumber, aged 34, had a contact burn of the second degree over the volar surface of the left forearm. The size of the burned area was 2 by 3 inches. After the part had been cleansed of dirt, strips of sterilized gauze soaked in the hydro-alcoholic picric acid solution were applied. Over the gauze was placed a light covering of dry absorbent cotton, held in place by means of a light bandage. Two days later the patient returned for redressing, the original dressing being soiled externally. At this time the burn, although not healed, was clean, free from infection and apparently progressing nicely. A second picric acid dressing was applied. Three days later the patient experienced the first subjective symptoms of burning and moderate itching under the bandage. Examination revealed an acute inflammation of an erythematous nature, limited to the outline of the yellow-stained area of contact of picric acid. On the succeeding or sixth day

after the first application, numerous vesicles appeared which in some areas were agglomerated, and in some cases coalesced. There was considerable local edema about the reddened area. This acute stage lasted for four days, the only constitutional symptoms being a headache and an annoying insomnia. The itching during this period was almost unbearable. By the tenth day of the dermatitis calorica the acute lesions had involuted to an erythemato-squamous type, accompanied by considerable thickening and possibly infiltration of the skin. This stage was not unlike an eczema. This condition was somewhat resistant to therapy but in two weeks more the area was clean, with only a few crusts and scales remaining.

Case 2.—F. H. B., a boilermaker, aged 27, came in contact with a hot fire door, and received a second degree burn over the anterolateral aspect of the right thigh. The burn covered an irregular area of approximately 10 square inches, surrounded by occasional spots of vesication. The blisters were punctured and the same treatment employed as in Case 1, with renewal of the dressing on the second day following the accident. Four days later the stained area presented the same weeping erythemato-vesicular picture as in the previous instance. This stage was very transitory. The actual region of the burn appeared raw and irritated. At no time throughout the course of the dermatitis was the patient subject to any symptoms other than those relative to the burn itself. The lichenification in this patient was more pronounced than that in the patient in Case 1. Complete recovery occurred four weeks after the date of the accident.

Therapy.—The treatment followed was identical with that employed in cases of acute eczema. The affected areas were given a preliminary bath with *sapo mollis* and water. Removal of the excess picric acid was attempted by washing with saline solution followed by hydrogen peroxide. This was not so effective as successive spongings with alcohol as the solvent, followed by saline. Some authors have recommended lithium carbonate solution (1 dram to 1 quart of water) for removing picric acid stain from the skin, but this preparation is practically never found in the emergency hospitals maintained by industrial concerns. During the acute "weeping" or vesicular stage, the medicament should be of the nature of a clear lotion. The author employed compresses saturated with aqueous boric acid, advised by Lane (15) in the treatment of ivy poisoning. With the subsidence of the moist character of the lesions, powder mixtures and ointments are applicable. Aristol (di-thymol di-iodide) was used because thymol has the reputation of causing a dry scaly skin to become more moist; but this therapy was replaced by the boric acid ointment, which proved more successful. It is needless to say that the lesions were necessarily free from infection, before the aristol powder and boric acid ointment were applied.

Discussion

It is quite evident that these cases of poisoning did not occur because of the slight excess of picric acid in the 10 per cent. alcoholic solution, but rather because of the increased absorption rate of such a preparation. It is for this reason that the employment of alcohol in any amount is discouraged as a solvent for picric acid solution to be used locally. A common formula for the preparation of such a solution has been:

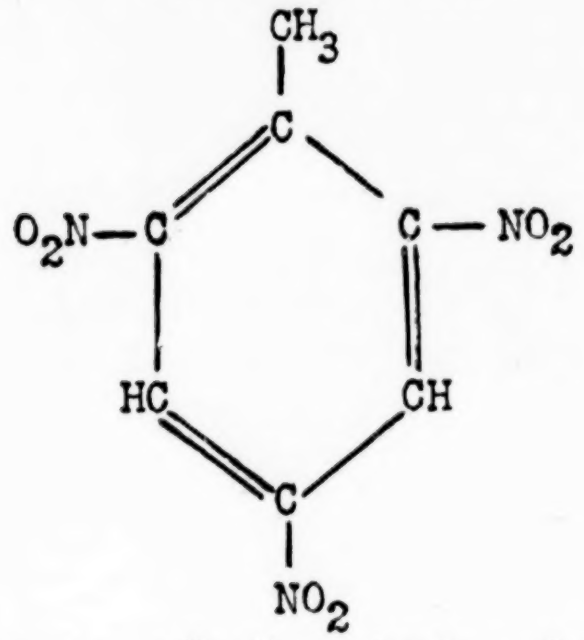
℞

Acidi picrici	ʒ ii
Alcoholis	℥ iiss
Aquae destillatae	O ii

An interesting fact was the lack of constitutional symptoms of any great degree. This is comparable to the dermatitis accompanying trinitrotoluene poisoning, the presence and severity of which bears no relation to the constitutional symptoms, although trinitrotoluene and dinitrobenzene (another similar agent) are absorbed mainly through the skin. The dermatitis occurring from

the application of picric acid in solution is much more acute than the dermatoconiotic type following contact with picric acid dust by workers. This latter is similar to trinitrotoluene dermatitis,

Trinitrotoluene

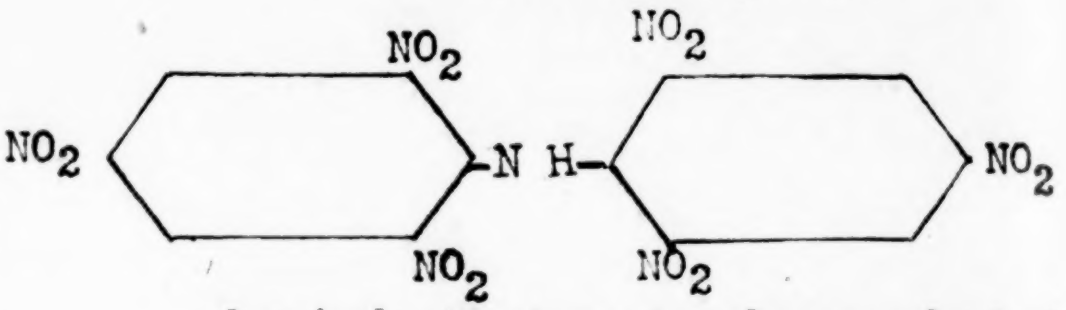


a common affection during the recent war (16).

Sequeira (17) reported many cases of dermatitis due to hexanitrodiphenylamine, a component of the explosive material found in bombs. This dermatitis, appearing about nine days after exposure to the irritant, presented dysidrotic vesicles and a yellow staining of the skin.

It is quite conceivable that here we have an example of the relation of

Hexanitrodiphenylamine



chemical structure to pharmacological action. The similarity of the skin lesions is in accordance with the chemical groupings. It is noted that there is a preponderance of the nitro groups in all three chemicals—trinitrophenol, trinitrotoluene, and hexanitrodiphenylamine; hence we may readily presuppose that this is the toxophoric radical. Trinitrotoluene is almost identical with trinitrophenol, except that there is a methyl radical in place of the hydroxyl group, thereby increasing the toxicity.

BIBLIOGRAPHY

1. Plimmer, R. H. A.: Practical Organic and Biochemistry. London, Longmans, Green & Co., 1918, p. 273.
2. Trinitrophenol. Pharmacopoeia of the U. S., 1916, 9th Rev., p. 471.
3. Trinitrophenol. U. S. Dispensatory, 20th Ed., 1918, p. 1164.
4. Wilcox, H. B.: Picric Acid as an Aid in the Treatment of Various Skin Lesions. Arch. Pediat., 1913, *30*, 854.
5. Hare, H. A.: Practical Therapeutics. Philadelphia, Lea and Febiger, 1918, p. 699.
6. Ehrenfried, A.: Picric Acid and Its Surgical Applications. Jour. Am. Med. Assn., 1911, *56*, 412.
7. Tidy, H. L.: The Strength of Picric Acid as an Antiseptic. Lancet, 1915, *2*, 604.
8. McGuigan, H.: Chemical Pharmacology. Philadelphia, P. Blakiston's Son & Co., 1921, p. 97.
9. Schamberg, J. F., and Kolmer, J. A.: The Treatment of the Vaccination Site with Picric Acid Solutions. Lancet, 1911, *2*, 1397.
10. Koizumi, T.: Ueber Vergiftung durch Pikrinsäure, welche in der Industrie gebraucht wird. Zentrlbl. f. Biochem. u. Biophys., 1914-1915, *17*, 615.
11. Adler: Wien. med. Wchnschr., 1880, p. 819.
12. Blyth, A. W.: Poisons; Their Effects and Detection. London, C. Griffin & Co., Ltd., 1920, p. 480.
13. Chéron, J.: Jour. d. therap., 1880, p. 121.
14. Sollmann, T.: A Text-Book of Pharmacology. Philadelphia, W. B. Saunders Co., 1918, p. 486.
15. Lane, J. E.: A Simple Treatment for Ivy Poisoning. Med. Rec., 1915, *88*, 442.
16. White, R. P.: Some New Forms of Occupational Dermatoses. Lancet, 1916, *1*, 400.
17. Sequeira, J. H.: Dermatitis from Explosives Used in the Air Raid. Brit. Med. Jour., 1917, *1*, 894.

THE EFFECT OF ANILINE BLACK DYEING ON FACTORY WORKERS*

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THE Factory Department of the Home Office, London, in the summer of 1921, decided to review the question of the effect of aniline black dyeing on the workers, and it was found necessary to have blood examinations made. I was invited to carry out this part of the investigation, and the following paper deals with the results of the blood examinations and the conditions found at the different works.

PROCESSES

Aniline black dyeing is not a direct process like the dyeing of other aniline colors. Although there are several direct aniline black dyes on the market, the only method of producing a satisfactory aniline black is by an indirect method, the dye being actually manufactured on the cloth during the process. This end is attained by the oxidation of an aniline salt by sodium chlorate or sodium bichromate in the presence of some metal compound which acts as an oxygen carrier, such as copper sulphate or a ferric salt.

During the present investigation three different processes of aniline black dyeing were investigated: (1) the one bath process (hot and cold); (2) the steam process; and (3) the oxidation process.

The One Bath Process (Hot and Cold).—This method is used chiefly for yarn dyeing. The goods to be dyed are allowed to stand for about half an hour in a cold bath containing a solution of aniline hydrochloride and sodium bichromate; the bath is then brought to the boiling point and is kept at this temperature for half an hour. The material is then washed, soaped, sized, and dried.

The Oxidation Process.—This process is sometimes termed the copper sulphate method. The chemicals required are: an aniline salt, an oxidizing reagent (such as sodium chlorate), an organic acid (such as acetic or tartaric acid), and copper sulphate. The part of the process concerned in the production of aniline black may be subdivided into (*a*) mixing, (*b*) preparing, (*c*) aging, and (*d*) chroming, washing and drying.

Mixing is the preparation of the "liquors" through which the material to be dyed is run in the impregnating machine. Two liquors are prepared: the aniline liquor which may be made from aniline hydrochloride, but which is more commonly prepared on the premises by a combination of aniline oil and hydrochloric acid; and the bluestone liquor which contains copper sulphate and the other ingredients.

Preparing includes impregnating or padding and drying. The liquors are mixed and carried by hand or by pipes to an impregnating machine. This machine consists of a trough for the solution, and rollers that mangle the material, which then passes over drying cylinders to the "ager."

The ager is a closed chamber which can be heated to 110° to 120° F., or more. The material passes through it, over a series of rollers, and oxidation

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begins when the cloth is dry. The room may be fitted with doors and windows and corridors so that the material running through may be observed. Experience shows that the formation of aniline black takes place best in a damp atmosphere, and a little water vapor is therefore admitted. The chemical reactions which take place are very complex and not fully understood, but some vapor of aniline is evolved and it is almost impossible to prevent some of the vapor from escaping into the surrounding room at the places where the cloth enters and leaves. The ager need be entered only in the case of a breakdown or for the purpose of cleaning.

Chroming, or fixing, and drying complete the process.

The Steam Process.—This process is also known as the prussiate, ferrocyanide or Prud'homme method. It is employed in printing as well as in dyeing loose cloth because, though slower than the oxidation process, it is more under control, and the black is said to be more durable. As far as this investigation is concerned, the essential parts of the process are mixing, preparing, and steam aging.

The mixing is similar to that in the oxidation process, except that the ingredients of the second liquor are different. Preparing is also carried on as in the oxidation process. Aging is done in a steam ager, in contradistinction to the ager, or dry ager, of the oxidation process.

The steam ager is a chamber enclosing a series of rollers over which the material runs. It can be tightly closed, after which steam is admitted, arrangements being made inside so that condensation does not occur on the material. The ager has to be cleaned periodically and has to be entered in the event of a breakdown; in either case the steam is first turned off. The chemical reactions which take place are again complex; steam and aniline fumes may escape at the mouthpiece, at leaky joints, and at the ends of the rollers.

Chroming, washing, and drying complete the process as in the other methods.

Symptoms of Poisoning

The cases of aniline poisoning met with were all mild ones, the chief signs being pallor, blueness of the lips, ears and nails, with occasionally a blue line along the edge of the gums, tremor and dyspnea. The patients complained of lassitude, loss of appetite, nausea, dizziness, headaches, shortness of breath, and a feeling of weakness in the lower limbs. The appetite was generally very fickle, and it seemed to be a recognized practice for the men to take their meals when they felt inclined. Another common symptom which the men described was that on leaving the works "the air seemed too strong for them" and "caught them in the legs."

No acute cases of aniline poisoning were met with, although several such cases were described as having occurred in the past, usually as a result of some aniline oil having been spilled over a workman, as in a case described by Prosser White and Sellers (1).

Changes in the Blood

An examination of blood counts taken at the various works showed that they fell into two distinct groups. In Group 1 all the red cell counts were over 5,000,000 corpuscles per cubic millimeter; while in Group 2 most of the red cell counts were below 5,000,000 corpuscles per cubic millimeter. A

TABLE 1.—BLOOD CHANGES IN ANILINE BLACK DYERS (GROUPS 1 AND 2) AND IN WORKERS ENGAGED IN MANUFACTURE OF ANILINE OIL (GROUP 3)

Process	Works	Case	Hours Worked per Week	Description of Work	Number of Red Cells per C. Mm.	% of Hb.	Color Index	Number of White Cells per C. Mm.	Polymorph. Neutrophiles	Polymorph. Eosinophiles	Polymorph. Basophiles	Small Lymphocytes	Large Lymphocytes	Large Hyalines	Examination of Stained Films	Ventilation	Separation of Parts of Processes
								GROUP 1									
									%	%	%	%	%	%			
ONE BATH PROCESS (Yarn dyeing)	1	1	30	Mixer of aniline and chrome	5,660,000	95	0.84	7,500	76.0	0.5	0.0	11.0	11.5	1.0	Nothing abnormal.	No local ventilation.	Mixing in department with dyeing.
		2	30	Dyer	5,412,000	88	0.81	8,750	75.5	1.0	0.5	16.0	7.0	0.0	" "	No local ventilation but curtain.	Dyeing in department with mixing.
		3	30	Dyer	5,356,000	100	0.93	6,250	55.0	2.0	1.0	37.0	1.0	4.0	" "	Same.	
	2	4	36	General mixer	5,376,000	90	0.83	8,725	53.5	1.0	0.0	36.5	4.0	5.0	" "	No local ventilation.	Mixing in separate department.
		5	36	Dyer	5,124,000	95	0.92	5,000	53.0	3.5	0.5	31.0	10.0	2.0	" "	Same.	Dyeing in separate department.
		6	36	Dyer	5,248,000	100	0.94	6,250	59.0	2.0	1.0	26.5	4.0	7.5	" "		
	3	7	36	Mixer of aniline and chrome	5,752,000	104	0.90	5,325	60.0	1.5	0.5	30.5	4.5	3.0	" "	No local ventilation but window above.	Mixing and dyeing in same department.
		8	36	Washer, carries "liquors"	5,160,000	97	0.94	5,000	72.0	0.0	1.0	14.0	0.5	9.5	" "	Locally applied ventilation by means of a chimney.	
STEAM PROCESS	4	9	16	Mixer, and cleaner of steam ager	5,660,000	90	0.79	6,250	56.0	0.5	1.0	12.0	29.0	1.5	" "	Mixing in open air.	Mixing in open air, aging and chroming together.
		10	16	Mixer, impregnator and chromer	5,640,000	90	0.79	6,875	72.5	0.0	0.5	18.5	3.0	5.5	" "	Drying cylinders under hood and fan.	Impregnating and drying in one department.
		11	16	Impregnator	5,452,000	100	0.91	6,875	56.5	1.0	0.5	30.0	9.5	4.5	" "	Ager ventilated by a chimney.	
	5	12	7	Mixer	6,272,000	92	0.73	6,250	70.0	0.0	0.0	18.5	11.5	0.0	" "	In open air.	In open air.
		13	7	Steam ager	6,160,000	100	0.81	6,250	61.0	2.5	0.0	6.5	26.0	4.0	" "	Hopper and chimney to ager.	Aging in separate department.
		14	7	Drying chamber	5,568,000	86	0.77	7,500	58.0	4.5	0.0	24.0	11.0	3.5	" "	Hopper and chimney for impregnating machine and drying machine.	Drying and impregnating in one room.
		15	7	Tenter in	5,200,000	90	0.86	6,875	55.0	1.0	0.0	27.5	15.0	1.5	" "		
		16	7	Plaiter out	5,384,000	90	0.84	6,250	52.0	4.5	0.5	21.0	19.0	3.0	" "		
Average blood count					5,526,000	94.2	0.85	6,620	61.0	1.5	0.5	33.5		3.5			
								GROUP 2									
	6	17	30	Mixer and impregnator	4,604,000	85	0.92	5,625	66.0	1.0	0.0	20.0	5.0	8.0	Average size 7.2μ. Variation in size 5.0μ to 9μ. Slight polychromatophilia.	Under hot rollers but with a cross current of air.	Mixing, impregnating and aging in one department.
		18	30	Impregnator and ager	5,372,000	88	0.94	6,250	—	—	—	—	—	—	Average size 6.97μ. Variation in size 5.0μ to 8.5μ.	No local ventilation.	

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STEAM PROCESS	5	12	7	Mixer	5,640,000	90	0.79	6,875	72.5	0.0	0.5	18.5	3.0	5.5	..	..	Mixing in open air.	Mixing in open air, aging and chroming together.
		11	16	Impregnator	5,452,000	100	0.91	6,875	56.5	1.0	0.5	30.0	9.5	4.5	..	..	Drying cylinders under hood and fan.	Impregnating and drying in one department.
		13	7	Steam ager	6,272,000	92	0.73	6,250	70.0	0.0	0.0	18.5	11.5	0.0	..	..	Ager ventilated by a chimney.	
		14	7	Drying chamber	6,160,000	100	0.81	6,250	61.0	2.5	0.0	6.5	26.0	4.0	..	..	In open air.	In open air.
		15	7	Tenter in	5,568,000	86	0.77	7,500	58.0	4.5	0.0	24.0	11.0	3.5	..	..	Hopper and chimney to ager.	Aging in separate department.
		16	7	Plaiter out	5,200,000	90	0.86	6,875	55.0	1.0	0.0	27.5	15.0	1.5	..	..		
	Average blood count				5,384,000	90	0.84	6,250	52.0	4.5	0.5	21.0	19.0	3.0	..	..	Hopper and chimney for impregnating machine and drying machine.	Drying and impregnating in one room.
					5,526,000	94.2	0.85	6,620	61.0	1.5	0.5	33.5		3.5				

GROUP 2

STEAM PROCESS	6	17	30	Mixer and impregnator	4,604,000	85	0.92	5,625	66.0	1.0	0.0	20.0	5.0	8.0	Average size 7.2μ. Variation in size 5.0μ to 9μ. Slight polychromatophilia.	Under hot rollers but with a cross current of air. No local ventilation.	Mixing, impregnating and aging in one department.
		18	30	Impregnator and ager	5,372,000	88	0.94	6,250	—	—	—	—	—	—			
		7	19	50	Mixer and impregnator	4,164,000	brown pigment	—	8,750	71.5	0.5	0.0	14.0	10.5	3.5	Average size 6.97μ. Variation in size 5.0μ to 8.5μ. Average size 6.79μ. Variation in size 4.5μ to 9.0μ. Slight polychromatophilia.	Hood and pipe connected with fan; action weak.	Mixing in a separate room.
		20	50	Impregnator and drier	4,844,000	85	0.87	7,500	71.0	1.0	0.5	9.5	14.0	4.0	Average size 7.31μ. Variation in size 5.5μ to 9.0μ.	Hood and pipe connected with fan. Drying room enclosed.	Impregnating and drying in department with chroming.
		21	50	Ager	5,012,000	97	0.93	6,250	66.5	0.0	0.0	23.0	6.0	4.5	Average size 6.48μ. Variation in size 5.5μ to 7.5μ.	Under exhaust and fan.	In a separate room.
		8	22	48	Mixer	4,508,000	77	0.83	5,000	67.5	0.5	1.0	20.5	8.0	2.5			
			23	48	Mixer	4,960,000	83	0.84	6,562	65.0	2.5	1.0	16.5	10.0	5.0	Slight polychromatophilia.	Open air.	Mixing in open air, aging and chroming together.
			24	48	Impregnator											Nothing.	Impregnating and drying in one department.

	23	48	Mixer	4,960,000	83	0.84	6,562	65.0	2.5	1.0	16.5	10.0	5.0	Slight polychromatophilia. Nothing abnormal.	Open air.	Mixing in open air but under cover.
	24	48	Impregnator and drier	4,656,000	79	0.84	9,062	62.5	1.5	0.0	20.5	11.5	4.0	" "	Drying cylinders under hood; exhaust and fan and curtain.	Impregnating, drying, aging and chroming in one department.
	25	48	Impregnator and drier	5,928,000	96	0.81	3,750	53.5	2.0	0.5	30.0	10.0	4.0	" "	Hot air chamber with chimney.	
	26	48	Ager	4,996,000	84	0.84	6,250	72.5	1.0	1.5	17.5	3.5	4.0	" "	Aging machine with hood, chimney and fan.	
	9 27	48	Mixer	5,168,000	89	0.86	5,000	55.5	1.0	0.5	31.0	6.0	6.0	" "	Openings in roof.	Mixing in separate department.
	28	48	Impregnator	5,144,000	brown pigment	—	6,875	65.0	8.0	0.0	20.0	4.0	3.0	" "	Impregnator without hood and man standing under plaiter.	Impregnating, drying and aging in one department.
	29	48	Impregnator	4,984,000	"	—	5,000	50.0	0.0	0.0	46.0	3.0	1.0	" "		
	30	48	Ager	4,864,000	"	—	6,250	63.0	2.0	0.0	10.0	22.5	2.5	" "		
	31	48	Assistant ager	4,960,000	"	—	6,250	50.5	3.0	0.0	38.5	2.5	5.5	Very slight punctate basophilia.	Ager ventilated by two chimneys.	
OXIDATION PROCESS	10 32	32	Mixer	5,680,000	85	0.75	10,625	72.0	0.5	0.5	23.0	3.0	1.0	Slight punctate basophilia; slight polychromatophilia.	General ventilation by louvers in roof.	Mixing in a separate department.
	33	32	Mixer	5,376,000	87	0.80	6,875	59.0	1.5	0.0	22.5	17.0	0.0	Slight punctate basophilia; slight polychromatophilia.		
	34	32	Mixer	4,720,000	brown pigment	—	8,750	69.0	4.0	0.0	9.0	15.0	3.0	Nothing abnormal.		
	35		Impregnator	4,776,000	77	0.80	6,250	63.5	3.0	0.0	12.5	18.0	3.0	" "		
	36		Impregnator	4,824,000	75	0.79	7,500	69.0	5.0	0.5	16.5	5.0	4.0	" "	General ventilation Ager has a chimney.	Impregnating, drying and aging in one department.
	37		Drier at cylinders	5,952,000	90	0.75	6,875	60.5	0.5	0.5	30.0	4.5	4.0	" "		
	38		Ager	5,768,000	79	0.70	8,437	66.5	2.0	0.0	18.5	4.0	9.0	" "		
	39		Ager	4,704,000	71	0.74	7,500	51.0	1.0	0.0	38.5	6.5	3.0	Slight polychromatophilia.		
	Average blood count			5,039,304	—	—	6,834	63.2	1.9	0.3	30.8		3.8			
								GROUP 3								
	40	—	—	4,308,000	brown pigment	—	5,000	49.5	4.0	0.0	41.5	4.0	1.0	Slight polychromatophilia; no punctate basophilia.		
	41	—	—	4,624,000	"	—	4,625	63.5	2.5	0.0	32.5	0.0	1.5	Same.		
	42	—	—	5,260,000	"	—	4,625	58.5	2.5	0.5	36.0	0.0	2.5	Same.		
	Average blood count			4,730,666	—	—	4,750	57.2	3.0	0.2	38.0		1.6			

hird group included the blood findings
three cases of aniline poisoning in
en who were engaged in the manufac-
re of aniline oil; an opportunity for
xamining them occurred on an occa-
on when their symptoms justified the
ppointed surgeon to the works recom-
ending that they should be taken off
e particular work on which they were
ngaged. They are included here for
mparison with the cases met with in
e aniline black dyeing works.

In Group 1 there was no count which
as not within normal limits, and the
nly sign noticed in any of the men was
slight pallor, except in Cases 2 and 3
here the lips and ears were of a bluish
nt. The average blood count of the
ses in Group 1 serves as a convenient
andard for comparison with the cases
Group 2 and Group 3 (see Table 1).

The most striking difference between
e first and second groups is the differ-
ce in the percentage of hemoglobin.
Group 1 there are only two cases
here the percentage of hemoglobin is
low 90, while in Group 2 there are only
o cases where the percentage of hemo-
bin is over 90. The lowest percent-
e of hemoglobin met with was 71, but
six cases in Group 2, and in all the
ses in Group 3, a brown pigment was
und in the blood which made it impos-
le to estimate the percentage of
moglobin correctly. In four out of
se nine cases the pigment was suffi-
ntly marked to be obvious to the
ked eye when the patient's ear was
icked, and it was well demonstrated
placing a drop of the patient's blood
white blotting paper beside a drop
normal blood. In the other cases the
gment was not so obvious until coal
s was passed into the diluted blood
order to prepare it for comparison
th the Haldane standard tube; this made the brown pigment more obvious. Where the brown pigment was observed, the blood was examined spectroscopically but methemoglobin bands were not detected. The brown pigment observed in these cases is generally stated to be due to methemoglobin, and failure to detect it is ascribed to the fact that it is present in a lower proportion than 1 in 10 of oxyhemoglobin. Malden (2) failed to detect it in his cases, and it was not seen in the blood of the case described by Prosser White and Sellers (1). Curschmann (3) states that he has repeatedly been able to observe methemoglobin bands in cases of aniline poisoning when the hemoglobin content had fallen below 70 per cent., though even then only as a faint shadow.

It is doubtful whether or not the brown pigment seen in these cases is methemoglobin. In experiments on aniline poisoning in rabbits, Price-Jones and Boycott (4) observed two abnormal pigments in the blood: "(*a*) a brown pigment without any spectroscopical characters; (*b*) a pigment, probably brown, which shows a band in the red, but which is not methemoglobin." The nature of the brown pigment found in the blood of cases of aniline poisoning needs further investigation.

There are twenty-three cases in Group 2 and in fourteen of them the red cell count is below 5,000,000 corpuscles per cubic millimeter, the lowest being 4,164,000. In Group 3 two out of the three cases have a red cell count of less than 5,000,000 per cubic millimeter. Examination of the stained films showed a wider variation in size in Groups 2 and 3 than in Group 1, but the alteration in size was not very great. In Table 1 no note on variation in size has been made because it was hoped that it would be possible to measure the corpuscles, but

circumstances prevented more than a few measurements being made. Two hundred red blood corpuscles in cases 17, 18, 19, 20, and 21 from Group 2 were measured, and the average size was found to be 7.2μ, 6.9μ, 6.8μ, 7.3μ and 6.5μ, with a variation in size from 4.5μ to 9μ. Normal red cells average 7.4μ in diameter, and vary in size from 6μ to 8.75μ. No variation in shape was noticed in any of the groups.

Malden (2) states that "6 out of 13 [cases of aniline poisoning] showed basophil granulations in the red corpuscles. The number of cells affected varied from 2 or 3 in the whole film in the slight cases to 10 or 13 in every field of the microscope in the more pronounced ones. This reaction is of great significance, as it appears to be in aniline poisoning, as it is in lead poisoning, the earliest noticeable sign in the blood." In the present investigation only three cases, numbers 31, 32, and 33 in Group 2, showed any punctate basophilia, and in these cases only two punctate basophilic cells were seen in each film. Polychromatophilia was rather more common, but it was never very marked, only three or four such cells being seen in a film.

With regard to the leukocyte and the differential counts, no definite conclusion can be drawn. The counts in Group 3 seem to suggest that in the more severe cases there is a slight leukopenia and a slight relative increase in the lymphocytes.

A study of the cases in Groups 1 and 2 shows that in the anemia found in aniline black dyers there is:

1. A decrease in the hemoglobin content;
2. In some cases an alteration in the blood pigment;
3. A decrease in the number of red cells per cubic millimeter;
4. A lower color index;
5. In some cases slight alteration in the staining properties of the red cells;
6. Little alteration in the leukocyte count;
7. Little alteration in the differential count.

The chief changes in the blood condition are the diminution in the amount of hemoglobin and the formation of some other hemoglobin compound, probably of a more stable nature than oxyhemoglobin—changes which cause some degree of oxygen deficiency. The symptoms met with are those of oxygen deficiency. Following the change in the hemoglobin content there is a fall in the number of red blood corpuscles per cubic millimeter, which, though never very marked, is quite definite.

Conditions Found at the Different Works

One Bath Process: Group 1

Works 1.—The average number of hours worked per week for August and September was thirty. Mixing was done in a barrel in the same department in which dyeing was carried on. Water was added first, then hydrochloric acid, and then aniline oil.

Dyeing was done in a Klauder Weldon dyeing machine. After the machine was filled with the solution, the yarn was put in; it was first worked in the cold, then steam was applied and a curtain drawn down at the sides. There was no locally applied exhaust ventilation.

The manager of this works remembered one case of aniline poisoning which occurred in a man who had wiped up some aniline oil which had been spilled, and in this way got his skin and his clothes saturated.

CASE 1.—This man, a mixer of aniline and chrome, aged 44 years, had been an aniline black dyer for twenty-six years. Except for slight pallor, no signs nor symptoms of poisoning were observed. He said that he had never been affected by aniline, and that he wore rubber gloves when mixing.

CASE 2.—This patient, a dyer, aged 56 years, had been engaged in this work for twenty-one years. He displayed slight pallor, and his lips and ears were slightly blue. He said that he had never been affected by aniline, but that he had seen men faint in summer and have to be carried outside.

CASE 3.—This man, a dyer, aged 22, had been engaged in this work for six years. He was slightly pale, but he presented no other signs nor symptoms. He said that he felt faint and dizzy in hot weather.

Works 2.—The average number of hours worked per week for two months previous to inspection was thirty-six; but during the fortnight previous to our examination the number had been fifty-three per week.

Mixing was done in a corner of one department, not in the main department. There was no local exhaust ventilation. Aniline oil was put in first, then hydrochloric acid and water. The two liquors were conveyed to a tank near the dyeing machine, and thence by a pipe to the machine. There were two dyeing machines in a separate department from that in which mixing was done, and without locally applied ventilation.

CASE 4.—This man was a general mixer, aged 39 years, who had worked as an aniline black dyer for eighteen years. (The actual mixing took about one hour a day.) He displayed slight pallor, and slight tremor (he was a heavy smoker). He said that he had had no symptoms of aniline poisoning. When he was mixing, he always wore gloves.

CASE 5.—This man, aged 32 years, had worked as a dyer for eight years. The only symptom was slight pallor; he complained of no ill effects.

CASE 6.—This man, aged 43 years, had worked as a dyer for eight years. He displayed no signs nor symptoms of poisoning.

Works 3.—The number of hours worked per week averaged thirty-six for the year.

Mixing was done in tubs placed in a corner of the dyeing department. Water was put in first, then aniline oil, and then hydrochloric acid. The actual mixing took only about one hour a day.

Dyeing was done in the same department with mixing. The solutions were carried in buckets to the dyeing machine and were all mixed in it. There were two dyeing machines which were enclosed, and each had a chimney to the outer air. The steam was mostly diverted into the chimneys and little came out at the sides of the machines. The men did not stand near the machines when they were in action.

CASE 7.—This man, a mixer of aniline and chrome, aged 37 years, had worked at this occupation for fifteen years. His color was good. He said that he occasionally felt dizzy and drowsy, but that he had noticed no loss of appetite nor gastric disturbance.

CASE 8.—This man was a washer and carrier of solutions. He was 51 years of age, and had worked at this occupation for twenty-six years. He showed no signs nor symptoms of poisoning.

Steam Process: Group 1

Works 4.—The average number of hours worked per week was sixteen.

Mixing was done in a receptacle in the open air. Water was put in first, then hydrochloric acid, and then aniline oil.

Impregnating and drying were done in a lower department where the final mixing of the aniline solution with the other ingredients was made. The drying cylinders were under a hood and fan, and the cloth passed directly from them to the ager.

Aging was done in an upper room, which was connected with the preparing

room by a stairway. The steam ager was ventilated by a chimney opening into the outer air. It was entered about once a month, when there happened to be a breakdown, and on Saturday for cleaning, in preparation for which it was opened on Friday and allowed to cool.

CASE 9.—This man was a mixer and supervisor, cleaner of ager and chromer. He was 44 years of age, and had worked for five years in his present position. The symptoms observed were pyorrhea alveolaris, blue discoloration of the gums, slight pallor, lips and ears blue, and fingers cold. He said that he had occasional headaches, and felt drowsy in hot weather.

CASE 10.—This man was a mixer, impregnator and chromer, aged 71 years, who had been engaged at his present work sixteen and a half years. His teeth were defective, and there was a blue discoloration of the gums, but no obvious pallor.

CASE 11.—This man, an impregnator, aged 61 years, had been employed at his present work for six years. He had no teeth; his face was gray, and there were prominent veins on his nose. He complained of occasional headaches and dizziness.

Works 5.—In this plant the average number of hours worked per week was seven.

Mixing was done in the open air, the aniline oil being put in first. The impregnating and drying machines were in one department. The dyeing solutions were ladled out of a tub into the trough of the impregnating machine. This machine was under a hopper with a chimney for exhaust. The drying chamber containing the drying cylinders was also ventilated by a hopper and chimney. The ager was in a separate department.

The manager called our attention to the danger of "firing," which sometimes occurs after printing and before aging, when the cloth has become too dry on the drying cylinders. The cloth then burns, giving off aniline fumes. One man, who had left the company's employ before this investigation, came in contact with these fumes, vomited, became dyspneic, and had to stagger out into the open air where he recovered in about twenty minutes. He was not cyanosed.

CASE 12.—This man, aged 32 years, had worked two years as a mixer. He gave no signs nor symptoms of poisoning.

CASE 13.—This man, aged 26 years, had worked three years as an ager since the war, and five years as an impregnator previous to the war. He displayed no signs nor symptoms of poisoning. He said that he cleaned out the ager weekly but was never affected by it.

CASE 14.—This man, aged 27 years, had been in charge of the drying chamber for two years. He displayed no signs nor symptoms of poisoning.

CASE 15.—This man was a "tenter in," aged 16 years, who had worked at this occupation for one year. There were no signs nor symptoms of poisoning.

CASE 16.—This man, a "plaiter out," aged 16 years, presented no signs nor symptoms of poisoning.

Steam Process: Group 2

Works 6.—The average number of hours worked per week was thirty.

Mixing, preparing, and aging were all done in one department. Mixing was done in a barrel between the impregnating machine and the hot-air chamber, and the hot rollers were above it. There was a cross current of air from windows on each side and exhaust ventilation above. All the steam appeared to rise.

The cloth passed over hot rollers to the hot-air chamber which was exhausted by a fan. It was then transferred to the ager which was ventilated by a chimney in the roof opening into the outside air.

CASE 17.—This man was a mixer and impregnator, aged 40 years. He had worked

as a mixer for sixteen years. There was obvious pallor, and his lips and ears were slightly blue. He complained of headache due to fumes, especially when dealing with heavy cloth, and said that he sometimes got dizzy and drowsy in the summer. He said that "aniline catches a man behind the legs and makes him feel weak," but that "an hour in the fresh air cures."

CASE 18.—This man, an ager and impregnator, aged 26 years, had been employed at his present work for three years. He said that he was always pale and that his finger tips were always cold. He displayed no sign of poisoning on the day that the examination was made.

Both of these men were working in the same room but while the former showed signs of aniline poisoning, the latter displayed no definite signs. This was in accordance with the conditions found. The former worked for most of the day between an impregnating machine on one hand, mixing barrels on the other, and drying cylinders above; while the latter spent most of his time at the ager at the other end of the room, and was not so much exposed to aniline fumes from the cloth.

Works 7.—The average number of hours worked per week was fifty.

Mixing was done in a separate room and aniline oil was added first. We were told that about eight years before, when there was no exhaust ventilation, the mixer was liable to suffer from aniline poisoning, dizziness, and gastric disturbances. Since that time a hood with a pipe connected to an exhaust fan had been installed, but the action of the fan was weak on the occasion of our visit.

The impregnating machine was worked by two men and the mixer. The machine was under a hood and chimney connected with a fan. There was no need for the men to touch the cloth with their fingers but they put their hands in the trough containing the dye. The cloth passed from the impregnator through a hot drying room, and was then carried to the ager, which was in a separate department and was under exhaust ventilation with a fan.

CASE 19.—This man, a mixer and impregnator, aged 54 years, had worked in aniline for twenty-eight years. He was pale, his lips and ears were slightly blue, and his appetite was not very good. He said that he had had headaches and dizziness, and in hot weather had a tired, aching feeling. At his work he wore a leather apron for protection. He took his meals in the mixing room.

CASE 20.—This man was an impregnator and drier, aged 49 years, who had been employed at his present work for eighteen years. Except for slight pallor, he displayed no signs nor symptoms of poisoning.

CASE 21.—This man, aged 49 years, had been an ager for twenty-four years. He showed slight pallor and slight tremor (alcoholic history), but gave no other signs nor symptoms of poisoning. He said that he was affected only when the fan stopped, as occasionally happened; then he became dizzy and "went off his food."

In this plant, the worker last mentioned was the least affected; he was an ager, working in a separate room and not in such an atmosphere of aniline fumes as that in which the other two men worked.

Works 8.—The average number of hours worked per week was forty-eight.

Mixing was done in the open air, but under cover. Aniline oil was added first in the mixing. The two men who did the mixing wore aprons and leggings of sacking.

Impregnating, drying, aging, and chroming were all done in one department. The two dyeing solutions were mixed by the impregnator, and the impregnating was done in cold liquors. The drying cylinders were under a hood with a duct and fan, and were surrounded by a thick curtain hanging from the hood. The hot-air chamber was entered

only for repairing breakdowns, and then the doors and windows were opened for some time beforehand. The ager had a hood and chimney, and was exhausted by a fan.

CASE 22.—This man, aged 49 years, had been a mixer for two years. He displayed slight pallor and blueness of the lips, and complained of occasional dizziness.

CASE 23.—This man, aged 59 years, had worked seven years as a mixer. He complained of occasional loss of appetite; otherwise he gave no signs nor symptoms of poisoning.

CASE 24.—This man was an impregnator and drier, aged 33 years. He had been engaged in his present work for fourteen years. The symptoms observed were pallor and blueness of the gums. He complained of occasional headaches, and felt drowsy at the time of examination. He said that he ate nothing in the morning until 10 o'clock; then he had a meal by the cylinders.

CASE 25.—This man was an impregnator and drier, aged 36 years. He had been employed at his present work for sixteen years. He was pale, but gave no other signs nor symptoms of poisoning.

CASE 26.—This man was an ager, 38 years of age, who had been employed at his present work for three years. He displayed slight pallor, and complained of occasional dizziness, drowsiness and loss of appetite, with a feeling of heaviness in the stomach. He said that he had felt better since a fan was installed.

Four out of the five men had mild symptoms of aniline poisoning, and the blood picture was in accordance with the symptoms. It is curious that Case 25 working in the same room as the others and on the same machine as Case 24 should have no symptoms and should have a practically normal blood count, with regard to red cells and hemoglobin.

Oxidation Process: Group 2

Works 9.—The average number of hours worked per week was forty-eight for the month preceding our visit. Mixing was done in a separate department. The aniline oil was pumped into the mixing tank so that it need not be touched by the mixer; the oil was added to the solution last. The other ingredients were kept in a series of tanks and were conveyed by pipes to the mixing tanks. Ventilation was afforded by an opening in the roof. The foreman said that before this system was installed and put in a separate department the mixers suffered from indigestion, blueness of the lips and ears, and faintness.

Impregnating, drying, and aging were done in one department. The manager had just had a hood and chimney put over the impregnating machine. The combined drying cylinder and ager was ventilated by two chimneys leading to the outer air.

CASE 27.—This man, a mixer, had worked eleven years in the dye industry. For sixteen months he had worked on the new installation. He gave no signs nor symptoms of ill effects. He had seen men become cyanosed about the lips, especially in summer.

CASE 28.—This man was an impregnator, aged 46 years, who had been engaged in his present work for four years. He said that he changed color at times, and that his face was pale and his lips blue. He gave no other signs nor symptoms of poisoning.

CASE 29.—This man, aged 40, had worked one year as an impregnator. He had previously been an ager. He was pale and his lips were blue. He said that he sometimes was dizzy and drowsy, but had no gastric trouble. He said that in the past his legs had become tired, and on leaving work the fresh air was too strong for him, especially in the summer. He was previously an ager and entered the ager many times a day. He was under treatment for aniline poisoning at the outpatient department of the local infirmary for thirteen weeks in 1919. He said that he had felt "a different man" since the hood was put up over the impregnator.

CASE 30.—This man, aged 38 years, had worked for fifteen years as an ager. The symptoms observed were: pallor, faint blue line along the edge of the gums, and nails rather blue. He said that he had never had headaches, dizziness, or drowsiness.

Case 31.—This man was an assistant ager, 33 years old. He had been employed for ten years at his present work, but gave no signs nor symptoms of poisoning.

An interesting point arose in connection with Cases 28 and 29. Some time before our visit a plaiter down had been installed on the impregnating machine, and as the two impregnators were working between the impregnating machine and the plaiter down they got all the fumes available. The manager noticed that the men were being affected by the fumes and had the plaiter down removed, and a hood and chimney installed. Since then the men have improved in health.

The other men who had a blood count of less than 5,000,000 (Cases 30 and 31) worked under the cloth passing from the hot rollers to the ager. Neither of them had marked signs nor symptoms of poisoning but the blood count shows that they were being affected by the aniline.

Works 10.—The average number of hours worked per week was thirty-two, but there had been a rearrangement in the staff a few days before our visit; some men were transferred from another works which had closed down, so that although the average number of hours worked per week at this works for a month previously was thirty-two, this does not apply to the men transferred from the other works.

Mixing was done in a separate department ventilated by louvers in the roof. The "bluestone" and "aniline hydrochloride" solutions were run by separate pipes to the barrel near the impregnating machine, and were poured into the padding trough by means of a can. The impregnating, drying, and aging machines were in a large airy department with roof ventilation.

Case 32.—This man was a mixer, aged 45 years, who had been employed at his present work for eleven years. He displayed no pallor, but said that he got dizzy when cleaning out the tanks.

Case 33.—This man, aged 43 years, had worked for twenty-five years as a mixer. The symptoms observed were: slight pallor, lips blue, and blue discoloration at the edge of the gums. He said that he got dizzy in close, hot, or foggy weather.

Case 34.—This man, aged 56 years, had been a mixer for twelve years; he had been at this works for only one week. No pallor was observed. He had dermatitis on the dorsum of the hands, but he said that he had never worked in chrome.

Case 35.—This man was an impregnator, aged 47 years, who had worked six years as a padder. He had been at this plant only one day. Except for a slight tremor, he displayed no signs nor symptoms of poisoning.

Case 36.—This man had been an impregnator for ten years, but had been at this plant for only two weeks.

Case 37.—This man, aged 48 years, worked at the drying cylinders. He had been an ager for ten years previously, but had been at this plant only a few days. No signs nor symptoms of poisoning were noted. The man's color was good.

Case 38.—This man, an ager, 33 years old, had been in this plant only one day. He had previously been employed at the same work, however. Blue discoloration at the edge of the gums was the only symptom noted.

Case 39.—This man was an ager, 54 years old, who had worked twenty-three years at the drying cylinders and ager. He entered the ager three times a day, and cleaned it every week-end. There was a blue discoloration at the edge of the gums, his teeth were decayed, and he was sweating profusely. No other symptoms were noted.

It is difficult to draw any conclusion from this works because of the recent changes in the workmen employed. It will, however, be noticed that in Cases 34, 35, 36, and 39 there were no definite symptoms of absorption of aniline but that there was a definite change in the blood picture.

Group 3

The men whose cases are included in

Group 3 were employed in an aniline dye works, and at the time of our examination were engaged in the manufacture of aniline oil. These men were under daily observation by the appointed surgeon to the works, who said that they were "nearing their limit" at the time when the blood counts were taken.

CASE 40.—This man was a charge hand, aged 36 years. He displayed marked pallor; his lips and ears were blue, but his nails were normal. He complained of frontal headache and of shortness of breath. Three years previous to this examination he was affected with nausea and vomiting due to aniline, and had occasionally to be sent off work for a few days.

CASE 41.—This man was a charge hand, aged 34 years. His lips and ears were blue, and there was marked pallor, but his nails were normal. He said that he had had headaches recently, and felt the aniline "going into his legs." He said that he ate when he felt hungry.

CASE 42.—This man was 40 years of age. His lips were blue, and his face bluish gray. He had become dizzy after dinner on the day of our visit and had to be sent to the ambulance room. His last attack was two years previous to this examination.

CONCLUSIONS

Various opinions are held as to which process of aniline black dyeing is most likely to give rise to aniline poisoning. The number of works visited and the number of workmen examined are too small to allow definite statements to be made; but a few points are rather suggestive.

Three yarn dyeing works were visited and fell into Group 1. As they were working more hours per week than some of the factories in Group 2, it would appear that this process is less liable to cause symptoms of aniline poisoning than are the other two processes.

There is little choice between the steam process and the oxidation process as far as their effects on the workers are concerned.

One factor concerned in the production of symptoms is clearly brought out in Table 1—that is, the time worked per week. Under existing conditions the more the hours worked per week, the greater is the chance of the production of symptoms of aniline poisoning and of anemia.

Two other factors also appear to be concerned—namely, the application of local ventilation in the various parts of each process, and the separation of the various parts of the process in different rooms. The atmosphere in all works where aniline is used contains a certain amount of aniline vapor, as is shown by the discoloration of the woodwork or paper. The amount may be very small, as the same discoloration is noticed in the open air in the vicinity of aniline oil drums or mixing barrels; but in the neighborhood of the impregnating, drying and aging machines the air is more thickly charged with aniline vapor; while in places where steam is used more aniline seems to be carried in the water vapor.

The application of better local ventilation to the various machines concerned should effect an improvement in the health of the workers.

There may be a fourth factor concerned in the production of symptoms, and that is the individual susceptibility of a worker to aniline. In most of the factories someone reported having noticed that some men were more affected by aniline fumes than others. We found no evidence either to support or to disprove this statement.

We found slight symptoms and definite alterations in the blood picture in mixers, impregnators, steam agers and dry agers, but since some men are mix-

ers and impregnators, and others impregnators and agers, it is impossible to say from our present data which part of the process is most concerned with the production of symptoms.

This investigation was made possible through the kindness of Professor Dean, in whose department the laboratory work was carried out and who obtained a grant from the Manchester University to defray expenses. In addition my thanks are due to Dr. Legge, H. M. Senior Medical Inspector of Factories, who kindly placed much information at my disposal; and to Dr. S. A. Henry, H. M. Medical Inspector of Factories, with whom the investigation was made and whose help and advice have resulted in the publication of the preceding notes.

BIBLIOGRAPHY

1. White, R. P., and Sellers, A.: A Case of Acute Industrial Aniline Poisoning. Internat. Cong. of Occupation Diseases, Brussels, Sept., 1910.
2. Malden, W.: Some Observations on the Condition of the Blood in Men Engaged in Anilin Dyeing and the Manufacture of Nitro-Benzine and its Compounds. Jour. Hyg., 1907, 7, 672.
3. Curschmann, F.: Die Vergiftungen bei der Anilinfabrikation und ihre Frühdiagnose. Internat. Cong. of Occupation Diseases, Brussels, Sept., 1910.
4. Price-Jones, C., and Boycott, A. E.: Observations on the Changes in the Blood and Bone Marrow Produced by Experimental Aniline Poisoning. Guy's Hosp. Rep., 1909, *63*, 309.
5. Dearden, W. F.: On the Injurious Influence of Fast Aniline Black Dyeing Processes. Brit. Med. Jour., 1902, *2*, 750.

THE TREATMENT OF CONSTIPATION*

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FEW preventable and curable disease conditions are more common than constipation. Few are more important. Among the effects which may be more or less due to this condition may be mentioned lowered resistance to all infectious diseases, auto-intoxication, many cases of so-called rheumatic pains, neuralgia, headaches and backaches, hemorrhoids, appendicitis, obstruction and inflammation of the bowels, acne, eczema, and other skin diseases. There are, in fact, few pathological conditions in the causation or aggravation of which constipation may not be a factor; yet little serious effort is made by either health authorities or physicians to prevent or to cure this serious condition. It is not to be wondered that patent medicine manufacturers thrive on the sale of laxatives and cathartics. Their preparations offer the public relief equal to that which can be obtained from physicians, in many instances, and often in a more palatable form.

Constipation is commonly treated as if it were a disease in itself. It would be far more logical to recognize it as only a symptom in the vast majority of cases. To regard it thus would lead to a more general realization of the fact that, while some cases are the results of definite organic conditions, most cases are essentially functional, and in reality the malady which demands correction is the far too common one—namely, faulty habits of living. Perhaps this is recognized by physicians. It is contended, however, that the patient demands a pill and, as a living must be made, the pill is supplied. This contention is a double reflection on the one who makes it. It is the duty of the physician to give the patient not what he wants but what he needs. Moreover, most patients appreciate having their false ideas corrected. They wish to be instructed in hygiene—a fact proved by the attitude of patients in industry, by the popularity of the health columns in the newspapers, and by the very lucrative practices which a number of chiropractors have built in Cleveland chiefly by teaching their patients hygiene from the mere smattering which they themselves have gleaned.

All good physicians realize the importance of adopting hygienic measures in the treatment of disease; yet their greatest defect is their inability to teach their patients as much as they intend.

At our plant dispensaries, which serve an average of over a thousand working people, the majority of whom are young women, we have an unusual opportunity for testing the efficacy of hygienic treatment as well as the methods of teaching it, and, judging from results in over 125 cases, we have worked out what appears to be a satisfactory treatment for constipation.

Whenever, either at sick call or in the course of routine examination of employees, we discover a patient suffering from chronic constipation we carefully question him regarding his habits of diet, water intake, exercise, and regu-

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larity in trying to have a bowel movement. Usually this discloses serious faults of living which are probable causes for the condition. It also indicates to the patient that the condition is one of the penalties for his own failure to obey the laws of health.

After the catechism has been completed, the results which may follow continued constipation are pointed out to the patient. With women the great possibility of impairment of beauty by sallowness and the development of skin diseases is stressed, because most women are more easily influenced in this way than in any other, even if they have little beauty to lose. Men are shown that the condition will probably decrease their earning ability and perhaps cause them to lose time from work, at intervals, by lowering their resistance. Every effort is made to show them how this is likely to occur, for without knowing the underlying reasons for these hygienic instructions most persons are unlikely to follow them. Both men and women are reminded that the continued use of drugs will only aggravate the condition.

The next step is also more important than it may seem. The patient is asked whether he will follow instructions if the physician outlines a course of treatment directed toward the permanent cure of the condition. If the preliminary steps have been carefully followed, the patient will usually agree to do so; if not, further effort is made to sell the idea to him. Upon the failure to win an unqualified promise the matter is dropped, with the statement that if the patient will return when he is ready to follow instructions we will give them to him. This occurs rarely, but there is no other course open if instructions are not to be wasted. Those who promise to follow instructions are put upon the following diet which, while simple, apparently covers all the requirements for the conservation of health:

DIET LIST

Green foods: Two or more portions daily
Asparagus, lettuce, spinach, brussels sprouts, rhubarb, endive, beet and dandelion greens, swiss chard, celery, tomatoes, cress, kale, okra, cauliflower, cabbage, green onions, string beans.

Fruits: Two or more portions daily
Oranges, cranberries, berries, peaches, pineapple, melons, apples, pears, apricots, cherries, plums, prunes, grapefruit.

Starches: Not over six portions daily
Potatoes, beets, carrots, turnips, bananas, bread and other foods made from flour, macaroni or spaghetti, rice, cereals.

Proteins: One or two portions daily
Meats, eggs, cheese, hulled beans, peas, lentils.

Water: Eight glasses daily

Milk: Four glasses daily

Sweets: Not over one portion daily
Candy, cakes, cookies, sweet rolls, pies or other pastry, jams and jellies, ice cream sodas or sundaes, etc.

Objections may be made that this diet is unscientific, inasmuch as measurements are inaccurate, calories are not figured, and vitamines are not estimated. These things we admit. The greater part of the population will, however, not learn to measure their food accurately and to compute calories and vitamine content for many years. Meantime the duty of the physician is to teach these people hygiene, not in his language but in theirs. Our diet list represents an effort to translate some knowledge of dietetics into their language. It may be possible that they can follow it and still have an inadequate diet, but it is very unlikely. Our results

demonstrate that it is a great improvement over what many people have been eating.

In the beginning of this experiment patients were merely instructed to have daily two full portions of green vegetables, two portions of any fruit except bananas, which are classed with starchy foods, or berries, which appear to be distinctly constipating, and two quarts of water. This led to some misunderstanding, and when we learned that one patient had stopped eating meat entirely, thinking that we had intended him to do so, we had the complete dietary printed.

Patients are informed that, in addition to following the diet, they should have at least one hour of active exercise daily; that, in order to form a regular habit they should try for ten minutes or more at the same time every day to have a bowel movement, even though they feel no inclination to do so; and that they should never neglect a call to have a bowel movement. It is important that the reason for each provision in the instructions should be explained to the patient so that he may take an intelligent interest in following them. It should also be impressed upon him that he must carry out all instructions in order to be cured.

If the condition is of such long standing that the patient has been in the habit of taking laxatives or cathartics two or three times a week, drugs may be necessary for a short time. We have found only two which are useful. Bitter fluid extract of cascara sagrada is given nightly in doses of 30 drops until the patient has had a movement daily for a week. Then the dosage is decreased 5 drops and the reduction repeated whenever the smaller dose has had the same result for a week. Aromatic cascara is less efficacious. Mineral oil is also useful in some cases; many patients refuse to take it, however, because it feels oily in the mouth. Although phenolphthalein has an effect somewhat similar to that of cascara, we have not used it because it is reported to irritate the kidneys and to cause a skin rash occasionally. In only a very small percentage of our cases, however, was it necessary to prescribe any drugs.

Our first group of fifty-three patients seemed to show remarkable results; most of them were reported as cured when followed up by one of our nurses after periods varying from a few weeks to several months. Later groups checked by other nurses did not show such good results. It was noticeable that the percentage of persons whose condition was improved or who were cured varied with the temperaments of the four nurses. Consideration of this fact has led us to decide not to publish the actual statistics which are probably somewhat inaccurate. This is no reflection upon the nurses to whom much credit is due for following up our cases. Even the group showing the poorest results indicated that less than 25 per cent. of the patients had failed to obtain either a cure or considerable improvement.

Several patients reported after several months that they had had one relapse after obtaining relief, as a result of failure to observe the instructions, but that by again following the plan they had been cured. This suggests that we have succeeded in instilling, in some patients at least, knowledge which will enable them to avoid constipation for some time.

A considerable number of young women, who were anemic as well as constipated and who complained of dizzi-

ness and headaches, reported that these symptoms quickly disappeared after they adopted the diet; when seen after intervals of a few weeks they showed no signs of anemia. In a number of cases of acne, also, marked improvement resulted without other treatment.

Almost universally patients who followed the directions, even in part, reported appreciable improvement in their feelings of well-being, and a number of them, who had been underweight, gained several pounds. The best recommendation for the diet is that results were sufficiently marked in a number of cases to stimulate other employees to apply to us for the diet list.

Conclusions

1. Constipation is too serious a condition to be neglected by physicians.
2. The method of instructing patients is at least as important as the instructions themselves.
3. The majority of cases of constipation in working adults can be cured by dietetic and hygienic measures alone.

JET DUST COUNTING APPARATUS*

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THE apparatus described in this paper was designed by the author in connection with the work of the Advisory Committee on Atmospheric Pollution, which is now attached to the Meteorological Committee of the Air Ministry.

The necessity for some reliable method of estimating the amount and nature of suspended impurity in air became obvious early in the investigation, as a short summary of existing methods will show. An instrument for measuring dust would have many applications, and for estimating the quantity and nature of smoke pollution in the air of cities, the amount and nature of dust in factories, mines and similar places, some means is essential.

The following paper (1) reviews briefly the methods already known and (2) describes an instrument evolved, its development and method of use, together with the principles upon which it is based. A number of methods previously tried are described in an early issue of THIS JOURNAL (1), to which reference should be made for a bibliography of dust measurement.

Review of Methods

Impaction Methods.—In these methods dust particles are forcibly directed against surfaces specially prepared with sticky substances, such as glycerine, oil, gum, silicate of soda or resin. The impaction method has been used in different forms and in all cases reliance has been placed upon the sticky substances to bring about the adhesion of the dust particles to the surface. There are serious objections to the use of any such substance, which may be briefly summarized as follows:

The author has tried several experiments with different adhesives, such as liquid paraffin, Canada balsam in xylol, but found that no advantage was gained in this way. In fact, in all cases it was impossible to obtain any great efficiency when such an adhesive was used, since a high velocity in the jet impinging upon the glass surface is essential to efficiency but is incompatible with the existence of a smooth, sticky film at the point of impact; if the velocity is high enough to make the jet efficient, the sticky material is blown away, while on the other hand, if the velocity is low enough to preserve the sticky film intact, the efficiency is so reduced as to make the method useless.

This drawback is illustrated in Table 1, which shows a comparison of the results obtained by the use of a well-known instrument in which a jet, circular in section, is caused to impinge upon a glass surface coated with vaseline, with the results obtained by the instrument devised by the author. From this table it will be observed that the efficiency of the "jet and vaseline" instrument was of the order of 4 or 5 per cent. Clearly, very fallacious conclusions may be drawn from the use of an instrument of this type. It is, however, somewhat difficult to test its efficiency as there is no standard to which to refer.

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Condensation Methods. — Condensation of water on the dust particles is utilized in Aitken's dust counter and the koniscope; a fog is produced which, in the koniscope, is compared with a standard. No distinction is made between dust particles and other nuclei which may be effective in assisting condensation.

Electrostatic Precipitation. — This method has been used to trap the particles by precipitation of dust into a liquid; the liquid is then compared with standard suspensions. If the precipitation is on to a dry surface the amount may be weighed directly, or again an attempt to count the particles under the microscope may be made.

Agitation with Water.—In Palmer's apparatus the air is drawn at high velocity through 40 c.c. of water in a specially shaped vessel; this results in a great disturbance of the water and the production of spray. The loss of water by evaporation is made good from time to time; the water and suspended dust are finally made up to 100 c.c., and 1 c.c. of the dust is counted in a cell, after settlement.

Ultramicroscope. — Attempts have been made to count dust particles by an ultramicroscopic method but the results are not satisfactory; in counts which have been made in this way by the author the number of suspended particles in the air was always less than the number obtained in the jet record.

Settlement.—Methods of dust estimation depending upon the settlement of the particles upon prepared surfaces and a subsequent count of such particles obviously give incorrect results, since they do not measure suspended particles but simply dust which has settled on the plate during a given time. This number need not be even proportional to the amount in suspension, since it depends upon the temperature and degree of disturbance of the air, size, shape and density of the particles, etc.

Owens' Dust Counter

The general principle upon which the jet dust counting apparatus is based depends primarily upon the condensation of moisture on the dust particles in the air, and the subsequent trapping of these particles by the sudden deflection of a fine jet of air which is caused to impinge upon a glass surface. The number and nature of the particles are ascertained by microscopic examination of the resulting dust record.

When air which contains dust and a sufficient quantity of water vapor is suddenly expanded, a condensation of some of the water vapor takes place upon the dust as nuclei. This fact was utilized by John Aitken in his well-known dust

TABLE 1.—COMPARISON OF RESULTS OBTAINED WITH "JET AND VASELINE" INSTRUMENT AND OWENS' DUST COUNTER

(1)	(2)	(3)	(4)
	Number of Particles per C.C.[1]		Ratio (2) ×100 / (3)
Date 1922	Instrument Using Jet and Vaseline	Owens' Dust Counter	(*i.e.*, expressed as %)
Jan. 24	120	5,600	2.14
" "	320	6,100	5.25
Feb. 7	305 (5 c.c. sample)	5,480	5.56
" "	231 (10 c.c. sample)	5,480	4.22
Mar. 1	240	3,950	6.08
" "	210	3,950	5.32
" 10 morning	668	14,050	4.75
	657		4.68
Mar. 10 evening	348	8,020	4.35

[1]The particles varied in diameter from 1.3 microns down, averaging 0.5 micron.

counter (2), in which the air is admitted to a small cell where its pressure is suddenly reduced, with the result that a rain of water drops occurs upon the floor of the cell. The floor is divided into squares and is observed through a microscope placed above the cell; the number of drops which fall upon it can thus be counted. In this case the assumption is that each drop has condensed around a dust nucleus and that a count of the drops is the equivalent of a count of the dust particles. Under these conditions, however, water will condense on nuclei other than dust, and a count of the water drops is, therefore, not to be interpreted as a count of the dust particles. The majority of the dust particles suspended in air are so very minute, averaging perhaps half a micron in diameter, that they cannot be seen except under a high magnifying power, and the construction of the Aitken dust counter does not permit of a high magnification.

In the instrument now to be described the sequence of operation is as follows: A high velocity jet of air is caused to strike a microscope cover glass; the effect of this high velocity is to bring about a fall of pressure in the jet, accompanying which, and resulting from it, is a corresponding fall of temperature. This in turn causes a condensation of the moisture in the air upon the dust particles, which are thus projected wet against the cover glass, and, as the water evaporates, are left behind adhering to the glass.

Experimental Development.—The evolution of this instrument involved a large amount of experimentation, an account of which follows. In the early stages experiments were made with a round jet formed from a piece of drawn and bent glass tubing. This jet was fixed inside a small bottle in such a way that a microscope slip could be held within about 1 mm. of the orifice, so that when air was drawn from the bottle it entered through the jet, impinging upon the glass slide, where some of the dust was found to adhere. This apparatus was experimented with in order to find what the order of its efficiency was, and whether this could be improved by smearing the glass with sticky substances. The percentage of total dust adhering to the glass was not very high, probably about 20 to 30 per cent., and this was not improved by smearing the glass with sticky liquids, such as thick paraffin; the sticky liquids on the slides were blown away from the point of impact of the jet, thus making them ineffective. In any case the amount of dust caught was not sensibly increased by the use of such means. What caused the dust to stick to the glass, became therefore an important question.

In order to investigate this a form of jet was next designed which could be placed upon the stage of a microscope so that the process could be observed while the jet of air was striking the glass surface. A small brass holder was made, the floor of which was formed of a sheet of mica; at a height of about 1 mm. over the mica floor a circular cover glass could be placed and held in position by a screwed sleeve. A side connection to the holder enabled air to be drawn from the cell enclosed between the cover glass and the mica floor. In the mica floor a circular hole about 0.1 mm. in diameter was made; thus, when the jet was placed on the stage of the microscope and light was reflected upwards through the floor of the cell, the objective could be focused upon the cover glass immediately over the hole in the floor. When air was drawn out of the cell by means of a small air pump, or other means, the dust par-

ticles could be seen impinging against the lower surface of the cover glass.

By watching this process carefully it was soon observed that many of the dust particles were surrounded by small drops of liquid. In this way it was discovered that, under suitable conditions, the water in the air could be made to condense upon the dust particles just before they impinged upon the cover glass. In order to cause the jet, air has to be drawn from the cell, and this implies a reduction of pressure in the cell. Again, if the velocity of the jet is high, there is a material fall of static pressure in the jet itself, owing to loss of velocity head. Hence, the conditions are suitable for condensation. If, therefore, the air before entering the jet is saturated with moisture, or so nearly saturated that the reduction of pressure brought about as already described will result in supersaturation, water will be condensed upon the dust particles, and will in most cases evaporate immediately, leaving the particles adhering to the glass surface as the velocity of the air falls off after impact with the glass.

This form of jet was found so extremely sensitive that a small fraction of a cubic centimeter of air passed through the jet produced a rain of dust particles, too numerous to count except in very pure air. Also the record was of very small dimensions and therefore extremely difficult to find unless in the way already referred to, *i.e.*, by focusing first upon the orifice forming the jet and then racking up and focusing upon the cover glass immediately above the orifice. Again, owing to the small quantity of air required to give a record in this form of apparatus, it appeared likely that its use would involve error, as a sample taken might not be strictly representative. The apparatus was, therefore, modified and a form was made in which the orifice for producing the jet consisted of a slot of about 0.1 mm. in width and of any suitable length up to 1 cm., depending upon the size of the cover glass used (see Fig. 1). This form removed the foregoing objections as the quantity of air which could be drawn through the

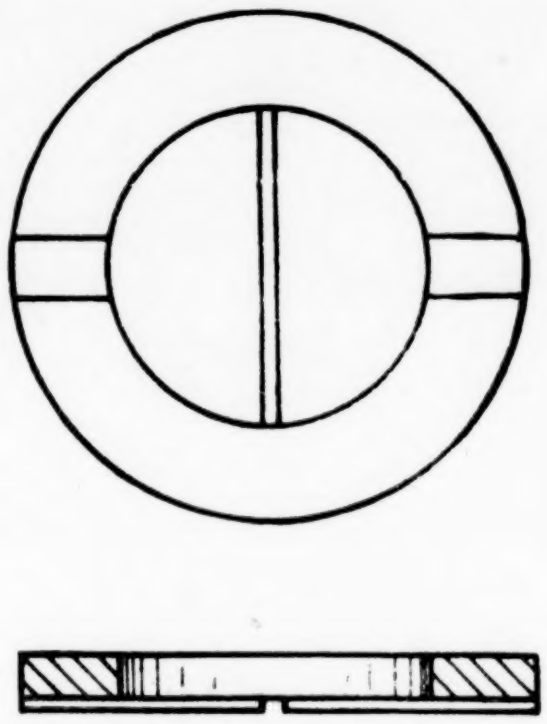

FIG. 1.—Slot 0.1 mm. wide and up to 1 cm. long.

jet without obtaining too many dust particles for counting could be greatly increased. Further, there was now no difficulty in finding the record on the cover glass, as the record itself was of linear form extending across the glass, the jet itself being of ribbon shape.

At this stage an attempt was made to measure the efficiency of the apparatus by means of a double jet, the second taking the air which passed through the first. An apparatus was constructed on the lines of that already described so that the operation could be watched under the microscope (Fig. 2). The lower cell had a slot B in its floor, the jet from which struck its roof, which in turn formed the floor of the upper cell and contained another slot A, so that the air having impinged upon its lower surface passed through the second slot and impinged upon the roof of the upper cell.

The construction of an apparatus with slots of this type was found to be comparatively easy in contrast to the construction of an apparatus with a round orifice of very small and fixed diameter. The slots were made in this apparatus by cementing the two halves of a cover glass to a metallic ring, the slot being

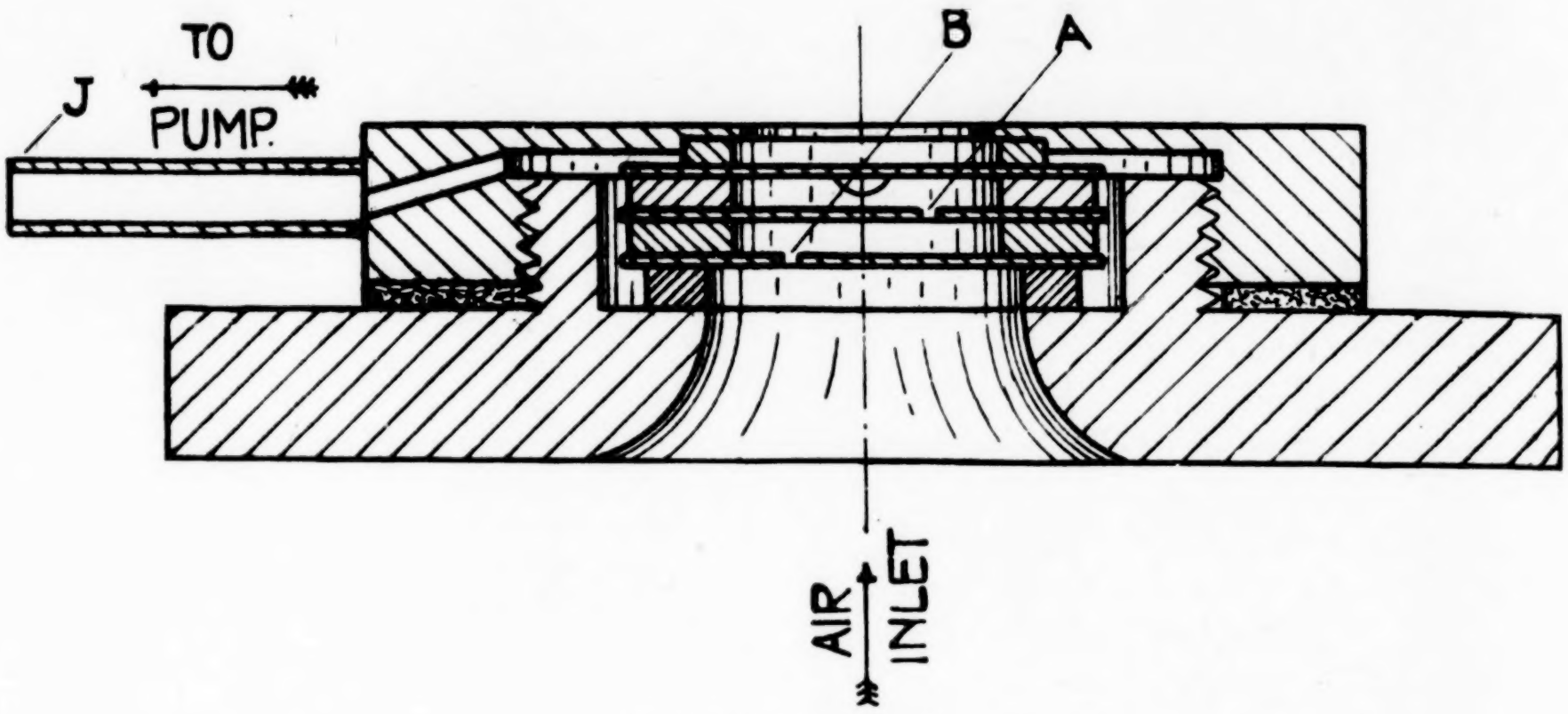

FIG. 2.—Double cell.

formed between the two straight edges, which were suitably ground and polished (Fig. 1). The arrangement of the slots was such that they were at opposite sides of the center of the apparatus. If the first jet stopped all the dust, there would obviously be no dust carried through with the second jet and none would be found on the roof of the second cell. Tested in this way it was found that a varying percentage of the total dust was trapped, sometimes 100 per cent., and at other times perhaps 50 per cent.

This method of testing the efficiency is not really satisfactory as it is possible that particles which escaped the first cell may escape the second. Again, as the adhesion of the particles is due to water condensation, the first cell may remove a sufficient quantity of the water from the air to reduce the efficiency of the second cell.

It appeared probable that variations in the quantity of dust trapped might be due partly to variations in the moisture contents of the air, as well as to change in dust contents; therefore a dampening chamber was devised through which the air had to pass before entering the jet. This chamber had its walls lined with damp blotting paper and was so arranged that the air would have to spend a certain minimum time in it before entering the jet.

The use of this damping chamber was found to make the records much more consistent, and, from recent results with the double cell method, it appears probable that all the dust in the air is trapped, or at least that the amount escaping is a negligible quantity. An attempt was made to measure the efficiency by means of an ultramicroscopic method, in which the number of particles suspended in the air was counted under a microscope while brightly illuminated against a dark background, and was

compared with the number obtained with a jet record. This method is very difficult to apply and is subject to great error owing to the extremely small volume of air used in the ultramicroscopic count. In all tests made so far, however, the number of particles counted ultramicroscopically was always less than that counted in a jet record. This is a result which might have been expected, since the visibility of the particles when examined in suspension in this way is a function of the intensity of the illumination and is also affected by the continuous brownian movements.

On December 1, 1921, a record taken by the jet gave 11,300 particles per cubic centimeter, and an ultramicroscopic count at the same time gave only 4,400. An interesting point to observe as bearing upon visibility of small particles is that the number of particles in the above record over 0.85 micron was approximately 3,500 per cubic centimeter. It must be remembered that while in the jet count a 1/12 inch objective was used, in the other a 2/3 inch objective was used, as it is not possible to use a high power for the ultramicroscopic count.

On January 22, 1922, during a bad fog in London, a count of a record taken by the jet gave 21,760 particles per cubic centimeter, while an ultramicroscopic count gave 18,870. There was an abnormal number of large particles during this fog, and it was observed that particles which settled to the floor of the cell used for ultramicroscopic count were approximately 0.5 to 0.9 micron in diameter, as measured under a 1/6 inch objective. A serious drawback to the ultramicroscopic method is the extremely small volume of air which is examined. In the case referred to, the actual volume in which the particles were counted was approximately 1.6 c.mm.

Perhaps the most satisfactory test of the efficiency of the jet was made with the aid of an instrument which the author had previously designed for the purpose of measuring the pollution of city air by smoke. In this instrument a measured volume of air is drawn through white filter paper of such texture that the suspended impurity is trapped and remains as a discoloration upon the surface. When air which had been passed through the jet apparatus was subsequently drawn through a white filter paper in this instrument, it was found that no discoloration was produced, while a similar volume of air which had not been passed through the jet gave a distinct discolored spot on the filter paper.

Present Instrument.—An instrument was designed for general use, as illustrated in Figures 3 and 4. The apparatus consists of a sleeve B, open at the top and bottom and screwed internally for the reception of a piece K, which forms a screwed plug. This is perforated by a central hole for admitting air to a narrow slot A, formed diametrically across the hole by means of two semicircular metallic plates, which are held in position by a ring R attached to the plug K. The upper surface of this ring is recessed to form a bed for a microscope cover glass, and the ring R under the cover glass is of such a thickness that when the cover glass is placed in position in its recess it forms the roof of a cell about 1 mm. high; the floor of the cell is formed by the above-mentioned metallic plates, the function of which is to form between them a narrow slot, approximately 0.1 mm. in width. The center of the ring R is turned out to a suitable diameter which in practice is found to lie between 2 and 10 mm.; the diameter of the central opening in this ring

also determines the size of the cell included between the cover glass and the metal plates forming the slot. The length of the slot A is also determined by the diameter of the opening in the ring, or of the central opening of the plug K.

Into the upper opening of the sleeve B fits a screwed plug C, to the inner end of which is fixed a three claw spring by which the cover glass is held firmly upon its bed, when the plug C is screwed home.

Between the plug C and the sleeve B, a leather washer H is provided, by means of which an air-tight joint is made when the plug C is screwed home. The sleeve B has an annular recess formed in its inner wall between the inner ends of the plugs C and K, and communicating with this recess is a connection E, for attachment to an air pump. Suitable channels N are formed in the upper surface of the ring R which receives the cover glass, as shown in Figure 4, so that when air is drawn from the space between the plugs C and K, by means of an air pump attached to E, a jet of air is caused to enter the slot A and impinge upon the cover glass, escaping to the annular space in B and the connection to the pump E, by means of the channels N formed in the upper surface of the ring R.

An approach tube, or chamber, T, is screwed to the plug K, as shown, and lined with absorbent material, such as blotting paper, held in position by suitable fastenings. During use the absorbent lining is wet with water, and its function is to supply moisture to the air before it enters the jet A. The capacity of this approach tube, or damping chamber, is two or three times that of the air pump attached to E.

When the apparatus is in operation, an ordinary hand air pump of a measured capacity per stroke is fixed to the connection E. In practice 50 c.c. capacity is found suitable, but this may be varied if desired. In taking a record of the dust the procedure is as follows:

After the air pump has been attached to the connection E, a few strokes of the pump are made so that the damping chamber T is filled with the air to be tested. The plug C is then removed rapidly and a carefully cleaned cover glass placed in position upon the ring R; after this has been done the plug C is replaced rapidly and screwed home. The pump is then operated so that one or more volumes of air are drawn through the jet A, a suitable interval being allowed to elapse between each stroke of the pump to permit the air in the damping chamber T to absorb water from the lining. The plug C is then removed, and the cover glass may be dropped out on to the hand by inverting the instrument.

The jet of air entering through A and striking the cover glass deposits its dust thereon. The cover glass may then be mounted for microscopic examination of the particles.

Method of Mounting Records.—The most convenient method of mounting records has been found to be as follows: Slides are prepared ready labelled, upon which are fixed tin rings of the diameter of the cover glass, that is, about 2 cm., a central cell of a little over 1 cm. being left. The rings are fixed to the slides by means of a special adhesive, which also coats the upper, or free surface, of the ring and which has the property of remaining sticky for several weeks. This adhesive is prepared from a mixture of resin and liquid paraffin. The rings are dipped in the melted mixture and placed upon the slide.

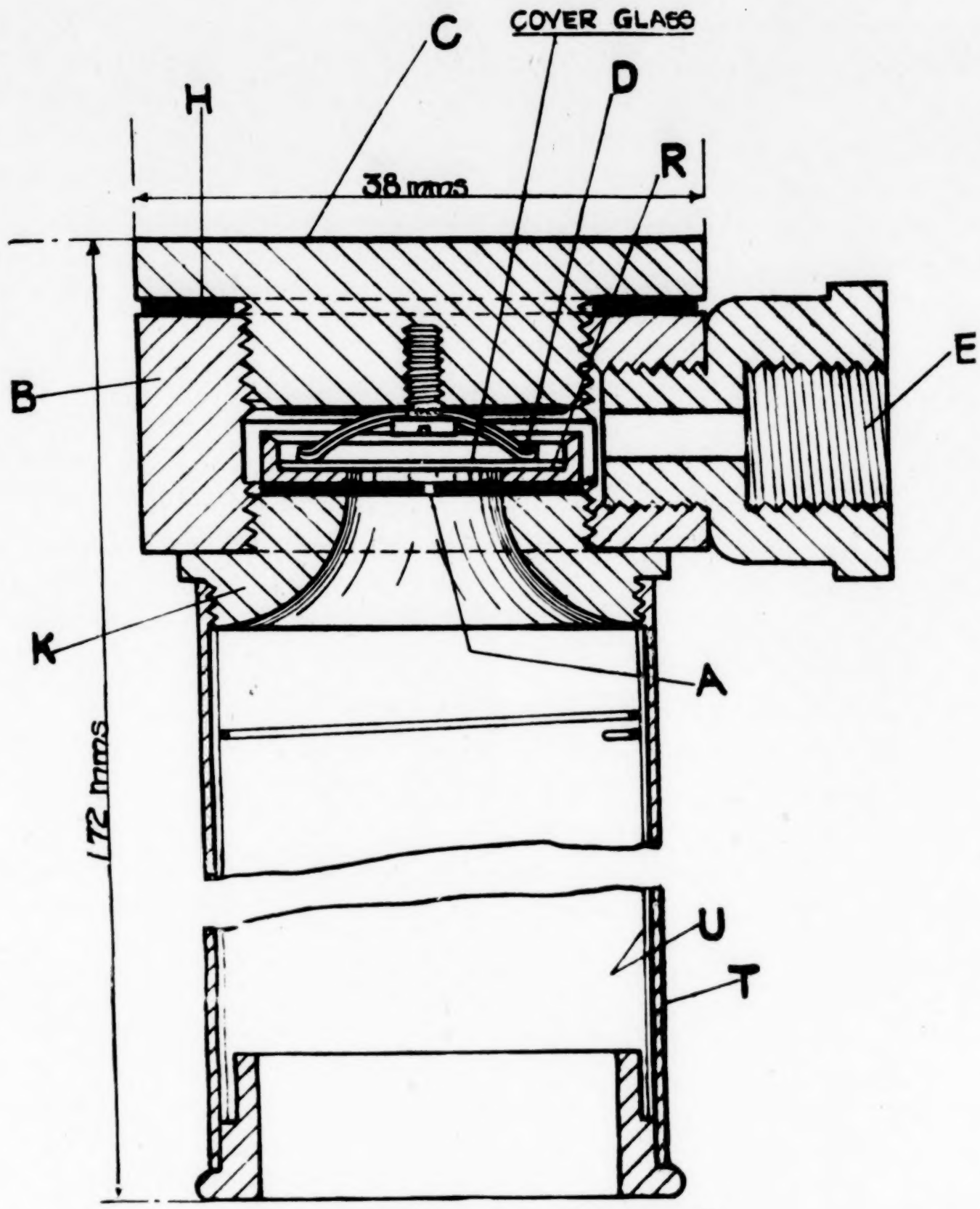

FIG. 3.—Vertical section of apparatus.

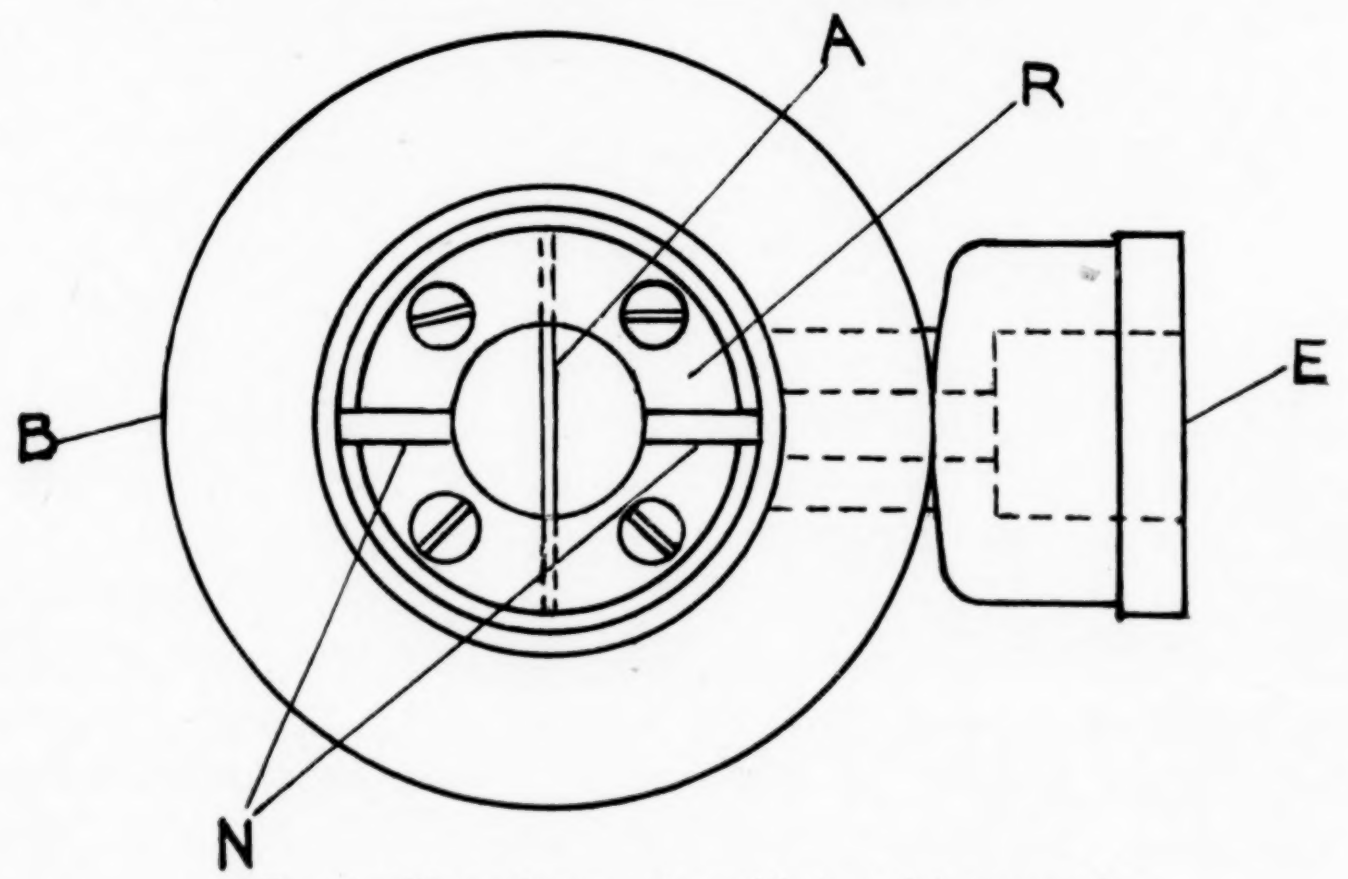

FIG. 4.—Plan of apparatus with top plug removed.

When it is desired to mount a record the cover glass is placed with the record downwards upon the top of the ring and pressed down gently with the thumb. The heat of the thumb is usually sufficient to soften the adhesive and to cause the cover glass to stick firmly all around.

A considerable amount of difficulty was found at first in obtaining a method of mounting suitable for use under inconvenient conditions, such as would be met with outside the laboratory.

Method of Counting Dust Particles.—The form of record obtained is a linear deposit of dust of uniform width across the cover glass; this lends itself to a simple method of counting, as a micrometer eyepiece which is ruled in squares of about ½ to 1 mm. may be used, and the number of particles in a strip, the width of one of these squares and extending completely across the record, can be easily ascertained. The number of such strips contained in the record may be found once for all by calculation or by direct counting under the microscope. Knowing the volume of air drawn through the cell, a factor can then be worked out for each jet which, when multiplied into the count of one strip across the record, will give the number of particles per cubic centimeter of air. The counting is done under a 1/12 inch oil immersion objective. In the case of a jet which has been in use for some time, the factor is 13.3, assuming that 50 c.c. of air are drawn through. Thus, if N = the number of particles in one strip transversely across the record, 13.3 N will be the number per cubic centimeter. Although the condensed water is an important factor in causing the dust to adhere to the cover glass, this water evaporates as soon as the cover glass is removed as it is excessively small in quantity; therefore the record itself, after removal, contains no water drops. Thus, the error arising from the fact that drops condense around particles other than dust, such as ions, does not exist. Again, the method does not depend in any sense upon the color of the particles; hence it is applicable to dust of all kinds.

Results

In addition to counting the number of particles per cubic centimeter of air, the size of the particles and their shape can be easily ascertained by direct observation under the microscope; some information as to their nature may also be obtained by examination in polarized light, and by other methods to be described later.

Dust Counts.—As illustrating some of the results obtained from records by this instrument, a few typical dust counts are given below. During the dense fog in London on Sunday, January 22, 1922, a record of 50 c.c. taken gave 21,760 particles per cubic centimeter. The diameter of a large proportion of these particles was 1.7 microns, while the average diameter was about 0.85 micron. The number of large sized particles found during this fog was quite unusual, as such particles are usually very few. During the fog on October 26, 1921, the number of particles obtained per cubic centimeter was 20,800; the average size of the particles was 0.85 micron, and the maximum 1.7 microns. There was a considerable number of spherical particles up to 0.85 micron in diameter.

In comparatively pure air the volume drawn through the jet may have to be increased. For example, in samples taken during August, 1921, on the Norfolk coast it was found necessary sometimes to draw 1,000 c.c. in order to obtain

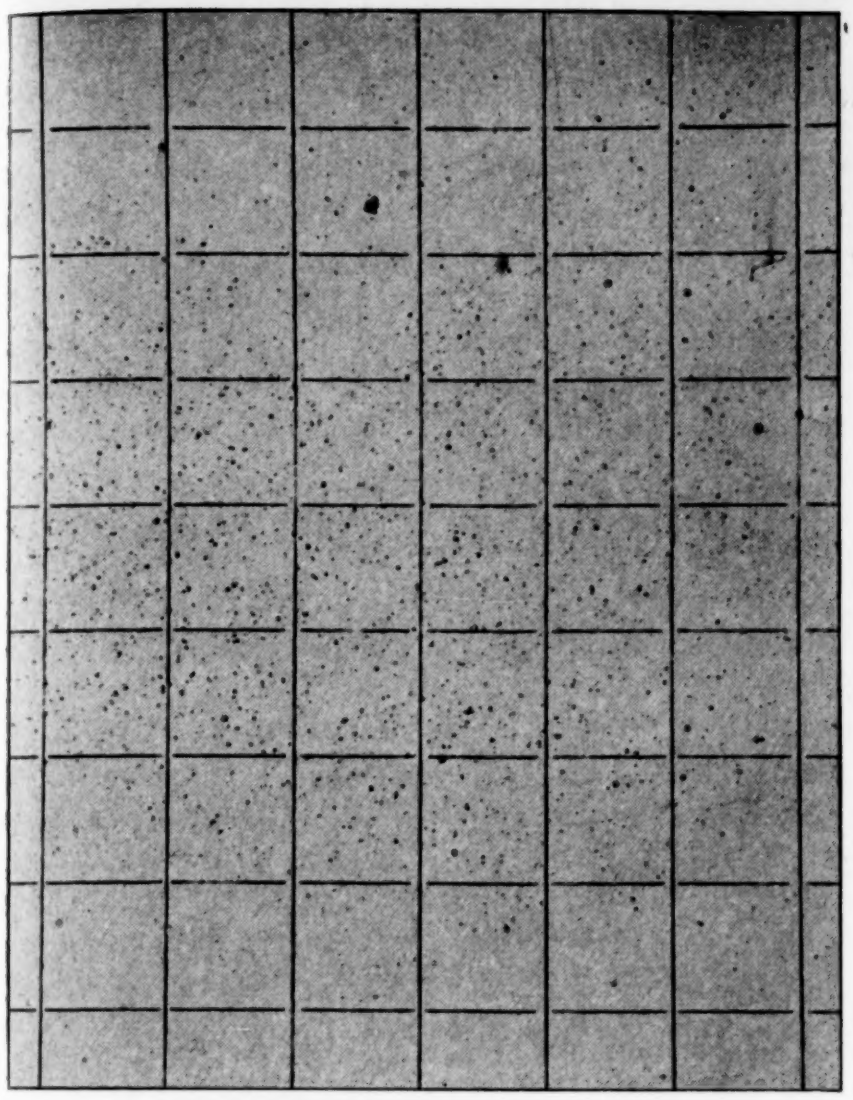

FIG. 5.—Record showing method of counting. The squares on the photograph are from the lines in the eyepiece micrometer. × 250.

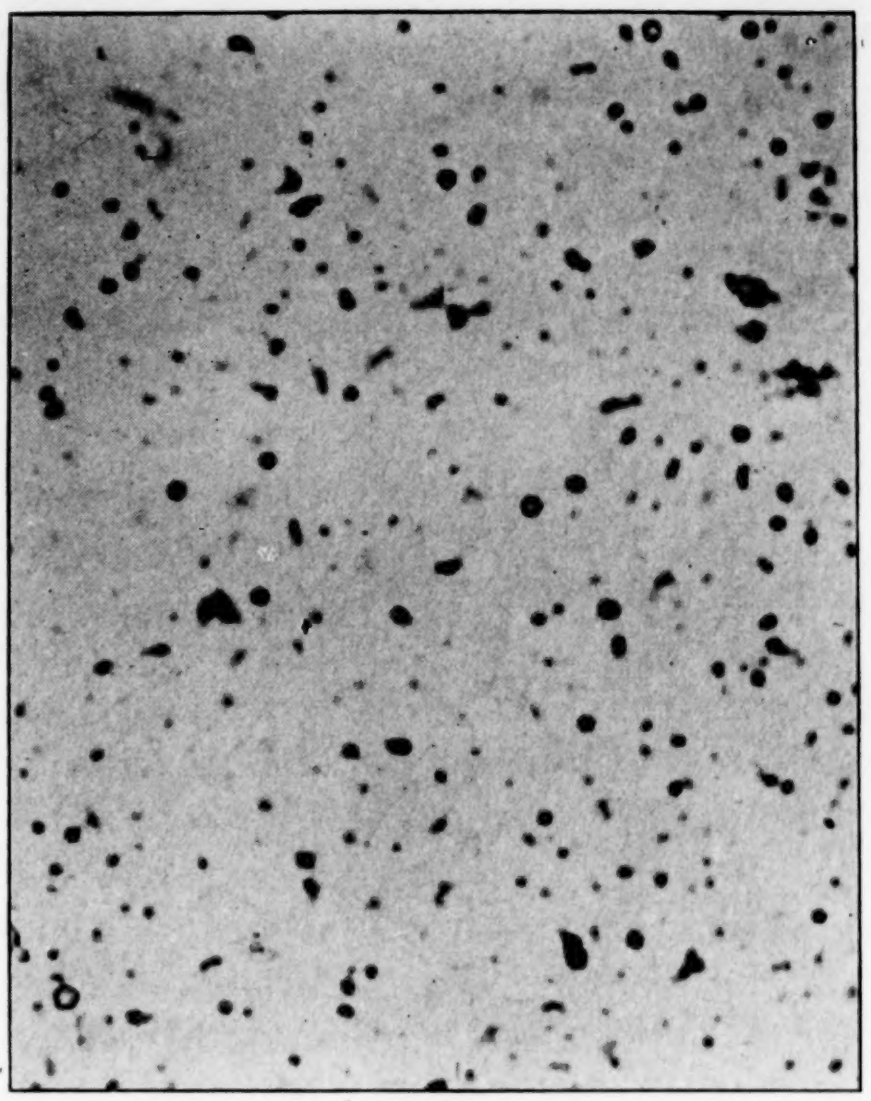

FIG. 6.—London smoke fog. × 2,000.

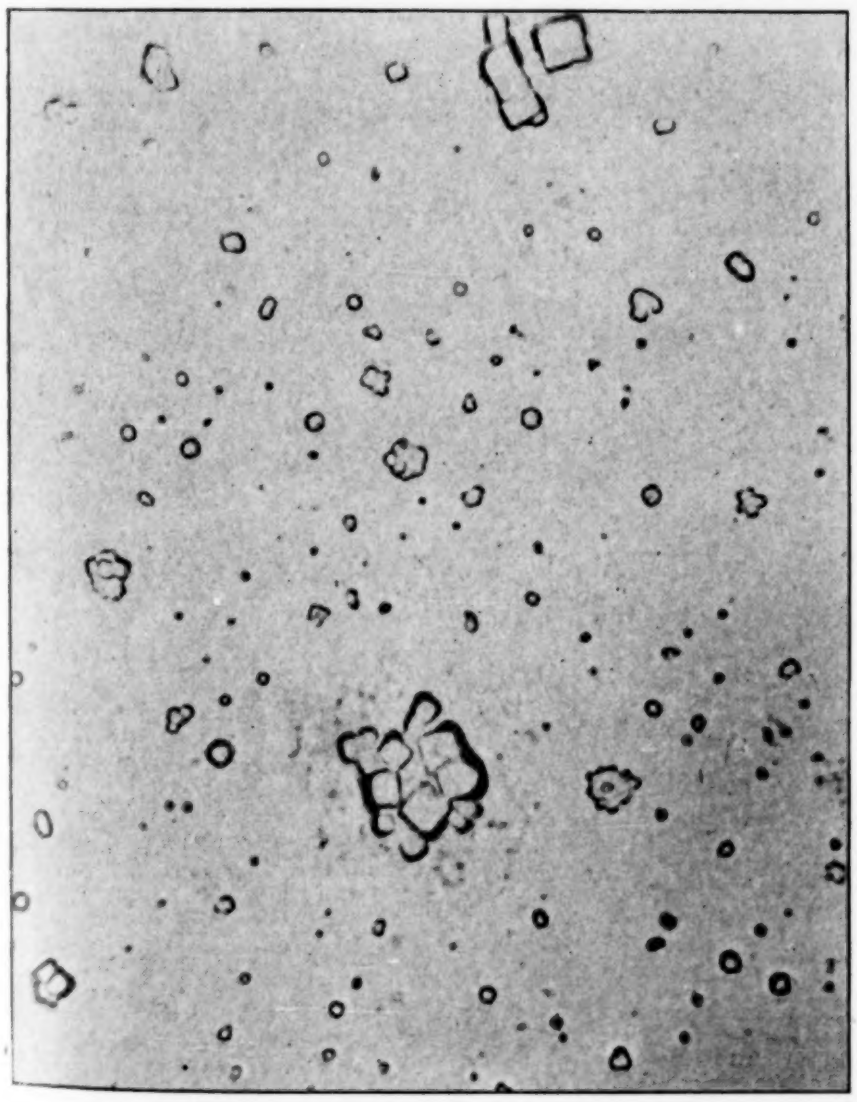

FIG. 7.—Record obtained in Villa Real de Santa Antonio, in southern part of Portugal. Practically all the particles are crystals of common salt. × 1,000.

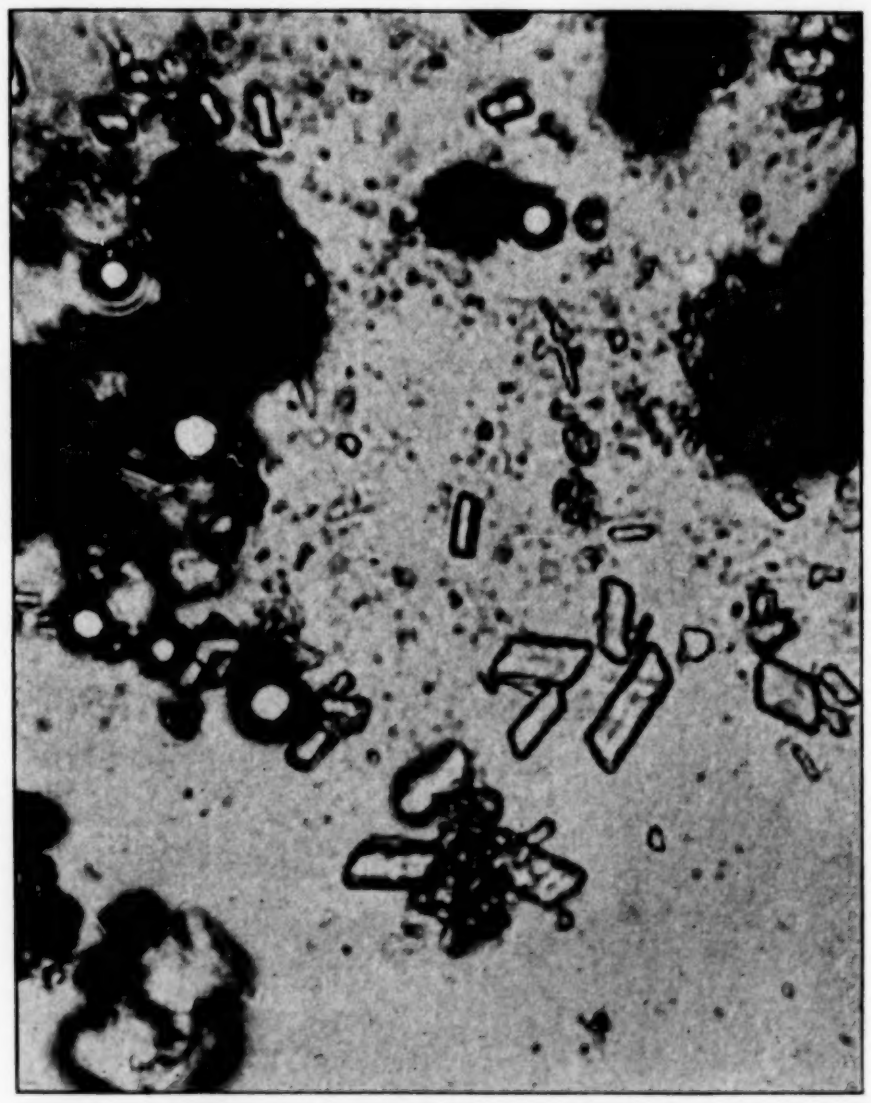

FIG. 8.—Record taken by means of filter pump at Cheam, in Surrey, 12 miles southwest of London, during northeast wind. Note crystals. × 1,000.

a suitable record; and during a slight haze in dry, sunny weather, about 100 to 200 particles per cubic centimeter were found, the size ranging from about 0.3 to 1.7 microns. These were found during a northeast wind and must have been carried across the North Sea from the Continent of Europe (3). A record taken at Cheam, in Surrey, on December 29, 1921, during a northwest by north wind gave 315 particles per cubic centimeter.

Dust in Expired Air.—One important application of the method has been to the discovery of dust in expired air. Since the experiments made by Tyndall (4), in which he examined expired air by means of a powerful beam of light from an arc lamp brought to a focus in the air by means of a lens, it has been very commonly assumed that expired air was dust free, although Tyndall stated that it was only air from the depths of the lungs that he found dust free. This matter was examined again by means of the jet apparatus. Air expired during ordinary breathing was found to contain about 70 per cent. of the dust particles which were breathed in; while the air from the depths of the lungs, after quiet breathing, contained from 2.5 to 7 per cent., and after deep breathing over 20 per cent. Inspiration was, in all cases, through the nose. This is a somewhat important result, since it throws some light upon the causation of dust diseases, such as silicosis. The author read a paper on this subject before the Medical Society of London on December 12, 1921, and the summary of conclusions arrived at from these experiments was given as follows:

1. The air passages do not act efficiently as a filter, except for the removal of very large dust particles.
2. When breathing dust laden air, it is only after a long period of quiet breathing that the air from the deep parts of the lungs approaches being dust free.
3. When the air from the depths of the lungs is dust free, it is not due to the removal of dust from the air in its passage to the alveoli but to deposit of the contained dust in or near the alveoli.
4. Normal quiet breathing may not carry any dust into the deeper parts of the lungs, and such dust as is carried into the air passages can be dealt with and removed by ciliary action.
5. Deep breathing following exertion or coughing, or accompanying sneezing or yawning, or by voluntary action, draws the dust into the deeper parts of the lungs, beyond the ciliated lining of the air passages, and thus beyond the mechanism provided for its removal.
6. It is suggested that during work in dust laden air it is the deep inspirations, resulting from the above causes, which are responsible for bringing about disease.
7. Nose breathing does not protect against dust.
8. It is doubtful how far exercises involving deep breathing should be recommended to city dwellers under present conditions, owing to the polluted state of the air.

Microchemical Examination

The fact that the efficiency of the jet depends upon condensation of moisture has made possible other methods of examination of the suspended matter of the air. Referring to the illustration of the apparatus, it will be noticed that the damping chamber is of tubular form and when the instrument is in use it usually hangs downwards, or may be pointed in any desired direction, the apparatus being held by the pump. It was found that if the apparatus was held by the damping chamber, a curious result was brought about: The heat of the hand caused moisture to evaporate from the damp lining of the chamber in greater quantity than the air could take up, and thus a fog could be detected inside the chamber. A record taken under such conditions was so affected by impact of the water drops that it was uncountable.

The water flowed out sideways from the linear record, leaving the stream beds free from particles, which were stranded round the margin of each little stream.

This fact was pressed into service in the following way: It was found that when a large volume of air was drawn through the jet so that a perfectly opaque record was obtained, and during the process the damping chamber was slightly warmed, the condensed water striking the record flowed out sideways, as previously described, dissolving in its passage some of the soluble matter contained in the record, which subsequently crystallized out on the dried up stream beds, when the water evaporated. These crystals could then be examined microscopically and microchemically, and the nature of the salts forming them ascertained.

In order to simplify the recognition of such crystals, a set of standard slides was prepared. These slides had cover glasses on which crystals of the sorts most likely to occur in atmospheric dust were formed artificially. The following is a list of the standard crystals so prepared:

Ammonium chloride.
Potassium chloride.
Sodium chloride.
Ammonium sulphate.
Potassium sulphate.
Magnesium sulphate.
Sodium sulphate.
Potash alum.
Sodium thiosulphate.
Sodium nitrate.
Magnesium carbonate.
Ammonium acetate.
Sodium sulphite.
Ammonium nitrate.

In addition to these, slides of pure silica and alumina powders were prepared. By examining the crystals, comparing them with the standard slides, and measuring the interfacial angles and behavior under polarized light, it is probable that most of the salts in atmospheric dust can be recognized.

This phase of the investigation has been undertaken only recently, and has not been carried very far up to the present time.

Acidity and Alkalinity.—Owing to the effect of the condensed water referred to in the foregoing, it was thought that if a chemical indicator were used on the cover glass upon which the record was taken some information should be obtainable as to the acidity or alkalinity of the air. Cover glasses coated with a solution of gelatine in water, to which different indicators were added, were prepared and experimented with. The indicators tried were methyl orange, congo red, phenolphthalein, erythrosin (iodeosin). With regard to the methyl orange used in this way, it was found that since the color change was from red to yellow, or *vice versa*—that is, the film was initially colored either red or yellow—a change of color on the surface of the film, if sufficiently shallow, was not detectable. The same objection applied to congo red; whereas with phenolphthalein, in which the color change was from colorless with acid to pink with alkaline, the depth of color obtainable with a thin film was not sufficient to be recognized under the microscope. A further objection was the absence of a characteristic color for acid. Erythrosin was too difficult to apply as it required the presence of ether.

Following the gelatine experiment trials were made with filter paper colored with methyl orange or congo red. The method was to prepare some paper which had the characteristic color for acid or alkali but was as nearly neutral as it was possible to get, consistent with distinct coloration. Two half disks of each paper were then cut and fixed on

a suitable record; and during a slight haze in dry, sunny weather, about 100 to 200 particles per cubic centimeter were found, the size ranging from about 0.3 to 1.7 microns. These were found during a northeast wind and must have been carried across the North Sea from the Continent of Europe (3). A record taken at Cheam, in Surrey, on December 29, 1921, during a northwest by north wind gave 315 particles per cubic centimeter.

Dust in Expired Air.—One important application of the method has been to the discovery of dust in expired air. Since the experiments made by Tyndall (4), in which he examined expired air by means of a powerful beam of light from an arc lamp brought to a focus in the air by means of a lens, it has been very commonly assumed that expired air was dust free, although Tyndall stated that it was only air from the depths of the lungs that he found dust free. This matter was examined again by means of the jet apparatus. Air expired during ordinary breathing was found to contain about 70 per cent. of the dust particles which were breathed in; while the air from the depths of the lungs, after quiet breathing, contained from 2.5 to 7 per cent., and after deep breathing over 20 per cent. Inspiration was, in all cases, through the nose. This is a somewhat important result, since it throws some light upon the causation of dust diseases, such as silicosis. The author read a paper on this subject before the Medical Society of London on December 12, 1921, and the summary of conclusions arrived at from these experiments was given as follows:

1. The air passages do not act efficiently as a filter, except for the removal of very large dust particles.
2. When breathing dust laden air, it is only after a long period of quiet breathing that the air from the deep parts of the lungs approaches being dust free.
3. When the air from the depths of the lungs is dust free, it is not due to the removal of dust from the air in its passage to the alveoli but to deposit of the contained dust in or near the alveoli.
4. Normal quiet breathing may not carry any dust into the deeper parts of the lungs, and such dust as is carried into the air passages can be dealt with and removed by ciliary action.
5. Deep breathing following exertion or coughing, or accompanying sneezing or yawning, or by voluntary action, draws the dust into the deeper parts of the lungs, beyond the ciliated lining of the air passages, and thus beyond the mechanism provided for its removal.
6. It is suggested that during work in dust laden air it is the deep inspirations, resulting from the above causes, which are responsible for bringing about disease.
7. Nose breathing does not protect against dust.
8. It is doubtful how far exercises involving deep breathing should be recommended to city dwellers under present conditions, owing to the polluted state of the air.

Microchemical Examination

The fact that the efficiency of the jet depends upon condensation of moisture has made possible other methods of examination of the suspended matter of the air. Referring to the illustration of the apparatus, it will be noticed that the damping chamber is of tubular form and when the instrument is in use it usually hangs downwards, or may be pointed in any desired direction, the apparatus being held by the pump. It was found that if the apparatus was held by the damping chamber, a curious result was brought about: The heat of the hand caused moisture to evaporate from the damp lining of the chamber in greater quantity than the air could take up, and thus a fog could be detected inside the chamber. A record taken under such conditions was so affected by impact of the water drops that it was uncountable.

The water flowed out sideways from the linear record, leaving the stream beds free from particles, which were stranded round the margin of each little stream.

This fact was pressed into service in the following way: It was found that when a large volume of air was drawn through the jet so that a perfectly opaque record was obtained, and during the process the damping chamber was slightly warmed, the condensed water striking the record flowed out sideways, as previously described, dissolving in its passage some of the soluble matter contained in the record, which subsequently crystallized out on the dried up stream beds, when the water evaporated. These crystals could then be examined microscopically and microchemically, and the nature of the salts forming them ascertained.

In order to simplify the recognition of such crystals, a set of standard slides was prepared. These slides had cover glasses on which crystals of the sorts most likely to occur in atmospheric dust were formed artificially. The following is a list of the standard crystals so prepared:

Ammonium chloride.
Potassium chloride.
Sodium chloride.
Ammonium sulphate.
Potassium sulphate.
Magnesium sulphate.
Sodium sulphate.
Potash alum.
Sodium thiosulphate.
Sodium nitrate.
Magnesium carbonate.
Ammonium acetate.
Sodium sulphite.
Ammonium nitrate.

In addition to these, slides of pure silica and alumina powders were prepared. By examining the crystals, comparing them with the standard slides, and measuring the interfacial angles and behavior under polarized light, it is probable that most of the salts in atmospheric dust can be recognized.

This phase of the investigation has been undertaken only recently, and has not been carried very far up to the present time.

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a metal ring of the same diameter as the cover glass used in the jet apparatus. This ring was placed in the apparatus instead of the cover glass and in such a way that the linear record would be taken half on one paper and half on the other. This method gave somewhat promising results; a definite alkaline reaction was detected in one case. Only a few experiments on these lines have yet been carried out, and further experiments will be made using the most neutral filter paper obtainable.

A third method used was to crystallize on to the cover glass a little indicator from solution, and to take the record on a cover glass so prepared, care being taken to have the damping chamber warm while the record was being obtained. Experiments made on these lines point to this method as probably being the most sensitive, since definite indications of both acidity and alkalinity were obtained. During the dense fog on Sunday, January 22, 1922, the reaction of the dust collected was decidedly acid both to congo red and to methyl orange. On the Friday previous to this a definitely alkaline reaction was obtained. The acidity referred to does not necessarily imply the presence of free acid as both methyl orange and congo red are sensitive to salts, the latter particularly so to calcium salts.

Tests by Volatilization.—Another method of examination applied to records obtained in London was as follows: A very dense record having been made upon the cover glass by drawing through a large volume of air, approximately 1,000 c.c., the cover glass was removed and a shallow metal ring, about ½ mm. deep, was placed on top of the glass and the ring covered by a second cover glass. The lower glass was then heated gently over a gas flame, a drop of water being placed upon the exposed surface of the upper cover glass to keep it cool. After cooling, the upper glass was removed and on its surface was found a deposit of something which had been driven off from the record and condensed. On examination under the microscope this deposit was found to consist of small rounded drops of dark, oily liquid soluble in oil. This liquid was doubtless tar.

No crystals were observed but it is probable that by improved methods it will be found possible to obtain crystals volatilized from the record in this way.

BIBLIOGRAPHY

1. Bill, J. P.: The Electrostatic Method of Dust Collection as Applied to the Sanitary Analysis of Air. This Jour., 1919-1920, *1*, 323.
2. Aitken, J.: On the Number of Dust Particles in the Atmosphere. Tr. Roy. Soc. Edin., 1887-1890, *35*, 1. See also: Proc. Roy. Soc. Edin., 1890-1891, *18*.
3. Owens, J. S.: Suspended Impurity in the Air. Proc. Roy. Soc., Ser. A, 1922, *101*.
4. Tyndall, J.: Essays on Floating Matter of the Air. London, 1883, p. 46.

BOOK REVIEW

MERCHANT SEAMEN: THEIR DISEASES AND WELFARE NEEDS. By *W. E. Home.* Pp. 111. London: John Murray, 1922.

The picture drawn in this book of life at sea as lived by British seamen is the reverse of attractive. Dr. Home tells the history of the past, not in order to extenuate but to explain the present; thus, to take one instance, the Merchant Shipping Act, 1906, ordered ship owners to pay over to the Board of Trade wages due to deserters. Why? Because previously (and the custom is still surreptitiously honored) captains were expected to make life on board so unpleasant that crews deserted; then, of course, no wages were paid—an economical proposition for the owners. A new crew was then engaged, and the process was repeated. One captain boasted that his owners had not had to pay wages for five years; another who returned with his original crew was promptly dismissed! Traditions last long; and the spirit and conditions needed to incite desertion are not quickly altered.

Rear-Admiral Boyle Somerville told in Blackwood's Magazine in 1920 of the conditions which he found when he took over a great liner as an armed merchant cruiser. No proper accommodations for civilized seamen and firemen had been provided. The narrow depths of the forecastle sufficed; no place, this, at any time, for men. The firemen were in the deeper depths beneath. "Round the filthy sides of each den there were riveted as many iron bed-frames, one above the other, as spaces could be found for them, to the number of about fourteen. Each bed contained its proper human occupant, dirty and sweaty, just as he had come from the stokehold. . . . Each man, as he came off watch, whatever the day or hour, threw himself down on the bunk, just as he was, and there remained until it was time for him to go to his next turn of watch in the stokehold. . . . As for meals, when the time for them came round, the members of each den took it in rotation to go up to the cook's galley and bring down thence, in a large tin dish, the mess of meat and gravy, or whatever was provided. On its arrival, each man reached forth from his bed, took with his hand, out of the dish as it went by, his gruesome portion, and, lying there, devoured it. . . . There were no plates, knives or forks, no table on which to lay them, nor even a bench on which to sit down to eat."

COMPARATIVE MORTALITY FROM CERTAIN CAUSES AT AGES 25-65[1]

Occupation	Phthisis		Pneumonia		Accidents		All Causes	
	1900-02	1910-12	1900-02	1910-12	1900-02	1910-12	1900-02	1910-12
Seaman Merchant Service	262	260	125	126	257	199	1646	1485
Clergyman Priest Minister	55	45	34	28	9	13	524	443
Coal miner	89	76	86	64	123	118	885	727

[1]These figures do not appear in the book.

Dr. Home gives several descriptions of accommodation for seamen in ships of today, British and United States liners, and freight boats; great variety exists, but even the best hardly attain a reasonable standard of hygiene. The provisions of the Bill presented to the House of Commons in 1921 give some indications of this standard; in order to improve it the proposal is made that each seaman should have 140 cubic feet of space, but space for mess-rooms, bathrooms, and washing places, if provided, may be included in the 140 cubic feet! A death rate of 7.8 per thousand for the merchant service is compared with 3.3 for the navy and 3.0 for the army; even after the greater age of the seamen is allowed for, a serious surplus remains. Apart from accidents—for which cause of mortality the seaman is far ahead of all occupations—respiratory diseases, especially

pneumonia and tuberculosis, are unusually prevalent (see table); the latter disease is especially rife among Lascar seamen.

Attention is directed to what is being done for factory operatives and coal miners; and a plea is entered that seamen need welfare accommodation and welfare supervisors, a welfare fund such as that of the miners, and compensation for tuberculosis contracted at sea. They need good ventilation, and warm and dry quarters. Above all they need reasonable treatment and opportunities for healthy recreation at sea and in port, and last, but not least, continuous service.—*E. L. Collis.*

BOOKS RECEIVED

Books received are acknowledged in this column, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers and as space permits.

MENTAL CAUSES OF ACCIDENTS. By *Boyd Fisher.* Cloth. Pp. 315 with preface. Boston and New York: Houghton Mifflin Company, 1922.

LABOR PROBLEMS AND LABOR LEGISLATION. Second Edition Completely Revised. By *John B. Andrews,* Ph. D., Secretary, American Association for Labor Legislation; Joint Author, History of Labor in the United States; Member, President's Conference on Unemployment; Editor, American Labor Legislation Review. Cloth. Pp. 135 with table of contents. New York City: American Association for Labor Legislation, 1922.

FEEDING, DIET AND THE GENERAL CARE OF CHILDREN: A BOOK FOR MOTHERS AND TRAINED NURSES. By *Albert J. Bell,* A.B., M.D., Assistant Professor of Pediatrics in the Medical Department of the University of Cincinnati; Attending Pediatrician to the Cincinnati General Hospital, The Tuberculosis Hospital and the Christ Hospital; Member of the Medical Milk Commission, and Chairman of the Divisional Council on Child Hygiene, Cincinnati, etc. Cloth. Pp. 276 with table of contents, index and illustrations. Philadelphia: F. A. Davis Company, 1923.

PHYSICAL EXERCISES FOR INVALIDS AND CONVALESCENTS. By *Edward H. Ochsner,* B.S., M.D., F.A.C.S., President, Illinois State Charities Commission; Attending Surgeon, Augustana Hospital, Chicago. Cloth. Second Edition. Pp. 56 with preface and illustrations. St. Louis: C. V. Mosby Company, 1922.

SUBJECT INDEX TO VOLUME IV

This is a subject index to all the reading matter in the JOURNAL OF INDUSTRIAL HYGIENE, and one should, therefore, look for the subject word, with the following exception: "Book Notices" are indexed under this title on page 539. The name of the author follows the subject entry in parentheses.

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